**Week 3: Nutrient sources**

Types of nutrient sources:

Forages

Cereal grains

Cereal by-products

Fibrous by-products

Oils and oil by-products

**Forage**

Forage constitutes the largest proportion of diet for all classes of horses.

In the wild, forage is the entire diet of the horse.

The same is the case for many domestic horses.

Forages can be grazed directly, such as fresh grass, or conserved (made into hay).

The natural environment for horse is to graze on fresh pasture.

Many domestic horses will spend a considerable time on pasture.

Some competition horses will spend considerable time in a stable and less time in pasture.

The natural diet of the horse is low-quality herbage, but a domesticated horse -- although it spends much of its time in pasture -- typically will graze on improved pastures, with much higher nutrient value than the natural pastures that the horse in the wild will typically graze and for which its GI tract was designed.

The chemical composition of pastures is extremely variable.

Protein levels can range somewhere from 3 to 30 percent, fiber from 20 to 40 percent, WSC content from 3 to 40 percent of dry matter.

Grasses typically contain little lipid content, no more than about 3 percent of dry matter.

Energy content of grass extremely variable. It can range somewhere from 7.5 to 12 megajoules per kilogram of dry matter, depending on the time of year.

Mineral content is also highly variable depending on the time of year.

A number of factors affect the chemical composition of grasses:

-- Time of year

-- Environment

-- Soil status

-- Herbage species

-- General management

-- Cutting and grazing strategies.

The time of year has a significant impact on the nutrient value of grass. Grass grows rapidly in spring and summer. Often, more grass grows than the animals can eat. In that case, it's common for grazed pastures to have some of the grass cropped for conservation (cut for hay).

There is less growth in autumn and winter, and pasture that has been conserved is useful during these months.

The types of conserved forages we typically feed to horses include hay, silage, haylage and high-temperature triforages.

The state of the growth of a pasture is the most important factor affecting its nutritive value.

As the amount of lignin increases in the cell wall of the plant, the digestibility of the fibrous component decreases. More mature plants have a reduced digestibility compared to younger plants.

Plant species also affects nutrient value as does soil type.

Grass responds well to soil with high fertility, and also soil type has a significant impact on the mineral content of pastures.

Environmental conditions also play an important part.

Temperature, light and rainfall all affect nutritive value, and particularly, they have a high impact on the WSC content of grass.

While the nutritional quality of grass can be extremely variable, nutritional intake is also difficult to estimate. Nutritional quality and growth typically means there will be higher intakes in spring and summer months, but it is very difficult to estimate the amount of grass eaten.

Most horses and ponies will eat approximately 2 percent of their body weight per day, but in periods where grass growth is rapid and there is an abundance available, too much grass can be consumed, particularly in spring and summer. Sometimes, horses and ponies must be removed from pasture or have access to a smaller amount of pasture.

We can conserve this excess grass for winter feeding.

Seasonal growth of pasture means we need to conserve forage for winter feeding.

Some horses are stabled year-round and will need conserved forage.

We also can use conserved forage as a grass management tool.

The objective of conservation is to preserve a product with as much of the digestible nutrients intact as possible.

The quality of preservation is key to the forage's:

-- Palatability

-- Longevity

-- Nutritional quality

-- Hygienic quality.

There are two ways to conserve forage:

We can remove all the moisture, making it stable under ambient conditions, such as hay making or artificially dehydrating forages.

Or we can acidify, or pickle, the forage in an anaerobic environment, making it stable and resistant to microbial degradation; examples are haylage and silage.

**Hay**

Hay is plant material dried to have a moisture content of about 15 percent.

It's usually dried in the field. This is highly weather dependent.

Because we're looking to remove moisture, hay is generally cut at a fairly mature growth stage. At more mature stages, plants contains lower moisture.

The down side, is more mature plants contain more lignin, which means they have a lower digestibility value.

Hay is stable at ambient conditions.

Sometimes, you can see changes occur, typically when hay has not been dried to a sufficiently low moisture content in the field.

The UK typically conserves grass as hay.

Other parts of world conserve other forage species, such as legumes (alfalfa is an example).

Hay is of variable quality both nutritionally and hygienically.

This is due to the stage of growth of the hay when it is cut, the environmental conditions during the drying period and any changes that may occur during storage of the crop.

Hay typically contains low energy values, 4 to 8 megajoules of digestible energy per kilogram.

A disadvantage is it can contain appreciable amounts of dust.

If hay is dusty, soak it, but for no more than 10 minutes. Fully submerge the hay in a bucket of water.

You're looking to minimize nutrient losses associated with soaking hay. WSCs, proteins and minerals are all soluble in water and can leach out into the water.

You also can steam the hay to reduce the dust content. Typically, you see less nutrient losses here compared to soaking.

Other types of forages can be used to make hay.

It's common to see lucerne (alfalfa) hay made in North America.

The UK is too wet; alfalfa has a higher moisture content, and it's hard to dry it in the UK.

Alfalfa has a higher level of protein and higher energy content. It has a digestible energy content of 10 megajoules per kilogram.

In the UK, lucerne can be saved by processing it with high-temperature drying.

This is drying forage at very high temperatures. It's a very efficient process but very expensive. The forage is dried in very large tumbler dryers. The forage is dried for a very short period time at 800 degrees centigrade (F). It can make use of young forage with a high moisture content. It has higher digestibility content because the fiber is much more easily degraded (lower lignin in less mature plants).

This drying process appears to have little effect on the nutritional quality of forage.

The disadvantage is the forage has to be chopped into short lengths to facilitate the drying process, so it's not suitable as a forage replacer because horses will eat it much quicker than longer-chopped forages, such as grass hays.

But it's a very good feed to add to the bucket feed to boost the nutritional quality of feed and add fiber to the diet.

The different types of forages that can be conserved by high temp drying:

Lucerne, or alfalfa

Grass

There is no data on the digestible energy content of high-temperature dried grass for horses. Sheep data suggest the high-temperature dried grass has a digestible value compatible to freshly conserved grass in the field.

Lucerne can contain appreciable levels of protein and energy. We can reduce this somewhat by mixing it with a lower value product such as straw. There are products on the market that mix alfalfa and straw to give a lower energy fibrous product suitable to add to the bucket feed for horses that are prone to weight gain.

**Video 2**

**Haylage and silage**

Acidification of hay such as making haylage and silage is an alternative way of conservation to drying.

Process takes high-moisture herbage and puts it in an anaerobic environment, where lactic acid bacteria on the crop ferments the carbohydrates in the crop to produce lactic acid. This drops the pH of the crop, and this drop in pH acidifies the crop and prevents the growth of spoilage organisms.

The difference between haylage and silage is the dry matter content of the crop. Silage contains higher moisture levels. The process is the same.

Generally, haylage and silage are made from grass. They can be made from other crops, such as alfalfa.

The process involves the crop being cut in the field, generally wilted overnight and siled either in a clump environment or wrapped in plastic using big fields.

Haylage is a commonly used forage for horses.

Typically, the UK feeds grass haylage. It's very popular because it has a lower dust content compared to hay and a higher digestible energy content. Typically, the grass is cut at a less mature stage of growth.

Haylage is highly palatable. Because it has a higher energy content than hay, there is less requirement to feed supplement feeds.

The downside is the aerobic instability. Once it is unwrapped and exposed to air, it starts to deteriorate. This is faster during periods where the environment is wam.

If feeding haylage in summer, it would deteriorate much quicker.

Lower temps in winter decrease the rate in which spoilage organisms grow.

Silage is generally perceived as high risk. This is due to the acidity of silage and the fact that it has a laxative effect on horses.

Studies don't show evidence of a different fecal pH in horses fed silage compared to hay. Also, only small differences have been detected in fecal dry matter of horses fed silage compared to hay.

However, there are concerns about the hygienic quality of silages. They can contain listeria species or clostridium botulinum. Horses can't metabolize the toxins from these organisms. It can have serious detrimental effects.

Because silage has higher moisture levels, it can support the growth of these organisms, which need water to proliferate. Haylage is perceived as a lower risk feed stuff for horses.

In summary, there are a number of forage sources for horses.

-- Fresh grass. Many horses spend a considerable amount of time in pasture.

-- Conserved forages. These include:

1) Hay, made from mature grass, which is variable in composition and has lower fiber digestibility.

2) High-temperature dried forages, typically from forages cut at less mature stages of growth. Because of the short chop, they can't be used in place of longer-cropped forages, such as hay.

3) Haylage has a high energy and lower dust content but may not be suitable for horses prone to weight gain.

3) Silage has been fed to horses but is perceived as high risk. Generally, feed haylage in place of hay.

**Supplementary feed stuffs**

**Cereal grains**

These are high in starch and contain high amounts of energy.

Depending on the grain, the digestible energy content can range from 12 to 16 megajoules per kilogram.

Cereal grains contain moderate levels of protein, but we consider them as having low protein quality.

Lysine is first limiting amino acid in the horse. Cereal grains are low in lysine content and, therefore, the protein quality is relatively poor in that respect.

Cereal grains are also low in calcium and high in phosphorous.

Mineral imbalances are important.

The ratio of calcium to phosphorous ideally is two calcium to one phosphorous. Cereal grains can create a considerable imbalance.

However, cereal grains are less variable in composition than hay.

Most commonly used cereal grains are oats, barley and maize. Others grains are used, but these are commonly found but in compound mixes. These include wheat, rye, sorgum and triticale.

Oats has a starch content of 40 percent of dry matter and, therefore, a reasonable energy content but also a reasonable fiber content due to the hull found on the outer of the grain. Unless you're feeding naked oats, and they have no hull; they have a lower fiber content.

Barley has a higher starch content. About 55 percent of the dry matter is starch. Barley is a higher energy source compared to oats.

Maize (corn) as the highest level of starch, around 70 percent of the dry matter. Therefore, it has a higher energy value than the other two.

Considering the digestibility of these cereal grains, starch is digested in the small intestine. It's undesirable for starch to pass through to the large intestine as it can cause disruption to the microbial population.

Almost all of the starch from cereal grain is completely digested across the whole of the digestive tract. But, there are differences between cereal grains.

Graph presented compares small intestine digestibility and total tract digestibility.

For maize, less starch is digested in the SI compared to oats and sorghum. All three pretty equal as far as total tract digestibility. This has important implications for feeding. We want feed stuffs where maximum starch digestibility occurs in the small intestine. Note that these results are for unprocessed cereal grains, and processing can improve SI starch digestibility.

**Processing**

Processing can involve simple mechanical processing -- rolling or grinding of the grain -- or more sophisticated techniques:

-- Micronization: using heat and mechanical pressure, using infrared technology, to disrupt the starch molecules, making them more available for SI digestion.

-- Extrusion: using high-temperature steam to make the starch more available for digestibility and then the grain being rolled into a flake prior to feeding.

Cereals do need to be processed for horses; we want to maximize SI digestibility.

Some cereal grains can be fed unprocessed. Oats, for example, which has a higher starch digestibility in the SI when fed whole compared to maize. Still, it's desirable that all cereal grains are processed before feeding to prevent the starch from passing to the LI and causing disruption.

The result if too much starch is passed to the LI:

We see rapid volatile fatty acid (VFA) production, which overwhelms the ability for these VFAs to be absorbed across the gut wall. This lowers the general pH of the gut environment. We also see an increase in the lactic acid bacteria present in the LI because these lactic acid bacteria ferment starch to produce lactic acid. This further reduces the pH. Then, the fiber-degrading bacteria designed to thrive in an environment in a pH of about 6.7 begin to die, and fiber degradation is reduced, fiber digestibility is lowered and the hindgut becomes acidotic, and the horse can become very ill and could lead to it developing other conditions such as laminitis.

Processing has a huge impact on improving small intestinal starch digestibility.

Graphic of maize being processed in different ways: whole, rolled or crushed:

Crushing the maize into fine particles significantly improves its SI digestibility. Whole maize has very low SI digestibility. It is highly undesirable to feed whole maize to horses.

We also need to consider the amount of cereal grains fed in one feeding.

Various studies have looked at how much starch horses can digest before it causes disruption in the LI environment.

In 2000, one study suggested that no more than 2 grams of starch per kilogram live weight should be fed per meal.

In 2009, another study suggested that no more than 1 gram per kilogram live weight per meal should be fed.

For a 500-kilogram (1,100 -pound) horse, don't feed more than half a kilogram (1.1 pounds) of starch per meal.

Take oats. It contains 40 percent starch. Don't feed more than 1.2 kilograms (2.64 pounds) of oats per meal to prevent any effect in the LI environment.

Take home message: We need to feed processed cereal grains, and we need to feed them little and often and no more than .5 kilograms per meal for a 500-kilogram horse.

In summary, cereal grains are energy-dense feed stuffs, and that energy comes from starch. They are of consistent nutritive value, and they do contain high levels of starch. High levels of starch in the diet can cause disruption to the LI environment, but starch in the diet is fine as long as it's fed in small amounts and at frequent meals. Cereal grains do need to be processed to feed to horses, and horses can tolerate cereal grains in their diet, but cereal grains must be fed as supplementary feedstuffs, and it is more important to ensure there is adequate forage provided in the diet and to make use of highly degradable fiber sources and to use cereal grains as supplementary feeds and not overshadow the forage provision with cereal grains.

**Video 3**

**Cereal and fibrous byproducts**

We need to be looking at including fibrous feed stuffs in horses' diet.

**Wheat bran**

Wheat bran is a major milling product fed in the UK; it arises from the milling of cereal grains.

It has been fed for a number of years, often as part of their ration on their day off.

However, it is quite poor as far as nutrition. It contains high levels of lignin, which reduces fiber digestibility.

It also contains low levels of calcium and high levels of phosphorous and can lead to a large imbalance.

It does have some value. It has a high water holding capacity and is a good vehicle for administering medicine.

Also, it is extremely palatable. It is a good appetite stimulant. It is often used to stimulate appetite in horses post surgery.

Another fibrous byproduct commonly fed to horses is **sugar beet pulp**. This is the residue remaining after the extraction of sucrose from the beet pulp. This residue is dried and then shredded or pelleted. Some has molasses added. However, you can buy it without molasses.

Sugar beet pulp has to be soaked prior to eating. Ingestion of large amounts of beet pulp unsoaked can cause choke and stomach distension in horses.

Shredded sugar beet pulp is should be soaked for 12 hours and pelleted for 24 hours. The main point is it should be soaked long enough to uptake a majority of water. This process can be sped up if you use boiling water.

In terms of nutritive value, it is an excellent feed stuff for horses. It has a high fiber content, but that fiber content is highly digestible. Its fibrous components are easily degradable by the microbes in the LI. Although it contains a lot of fiber, that fiber is highly digestible.

It contains moderate protein levels but favorable calcium levels, so, in terms of its calcium to phosphorous levels, it is much more favorable compared with cereal grains. Sugar beet pulp is very good cereal replacer. It has a uniform composition and a much more favorable calcium content. Because of its high fiber content, there's less risk of sugar beet pulp eliciting LI disturbances. It has high dry matter digestibility. The dry matter digestibility is around 85 percent, and it also has a high digestible energy value of around 30 megajoules per kilogram dry matter.

Often, it is added to bucket feeds but it's generally undervalued and underused. It is an excellent feedstuff for horses. We also find sugar beet pulp added to compound mixes. In compounds, it is presented in the dry form. However, because it's included at low levels, this does not pose problems with choke or stomach distention.

Some has molasses added. Molasses is the residue following sugar extraction from the sugar beet root. It is a thick residue after the sugar is separated from the water extract. Molasses is high in soluble sugars. It is often added to sugar beet pulp, and it's often included as well in these compound mixes, also known as course mixes, and it's generally a component of mineral licks, as well.

It is high in energy because of the high sugar content. It has low protein content and high carbohydrate content. It is not suitable for horses prone to weight gain.

**Oils and oil byproducts**

Vegetable oils are commonly fed to horses.

Types commonly used for horses include corn oil, soy oil, sunflower oil, rapeseed oil and linseed oil.

Some studies have looked at palatability. Corn oil is most palatable for horses.

Fish oil is also included in horse rations, particularly cod liver oil.

Most oils have a similar energy content, 9 megacals per kilogram. 2.25 times more than that of carbohydrates. They are very energy-dense feed stuffs.

Typically, they are added to the ration to improve the energy value.

Oils also have other benefits. Studies have shown, they provide:

-- Improved energy efficiency

-- Improved athletic performance

-- Enhanced body condition

-- Less excitable behavior

-- Improved health benefits (often seen with inclusion of fish oils).

Oil byproducts are also included in horse rations.

Seeds that are grown specifically for their high oil content have this oil extracted and used for human purposes. The residue remaining is referred to as the oil seed meal. This is particularly high in protein. Therefore, these oil seed meals are generally used as protein supplements. They do contain some oil content, and that depends on how the oil has been extracted. If a solvent used to remove the oil, the oil content is about 1 percent. If mechanical processing used, the oil level is around 5 percent.

Different types of oil seed meals: soybean meal, linseed meal and hempseed meal.

The important thing to consider is whether the oils have high levels of protein and good quality of protein.

Soybean meal has high levels of lysine, the first limiting amino acid in horses.

**In summary:**

It's very important to use feed stuffs that are of high quality and extremely important to include high levels of forage.

Any supplementary feeding should start with the use of highly degradable fibrous feedstuffs, such as sugar beet pulp.

Cereal grains are an important component of many horse diets, particularly for horses in harder work such as racehorses. But these contain high amounts of starch. They should only be used as a supplement to a fiber-based diet and fed in moderation and fed little and often to avoid LI disturbances.