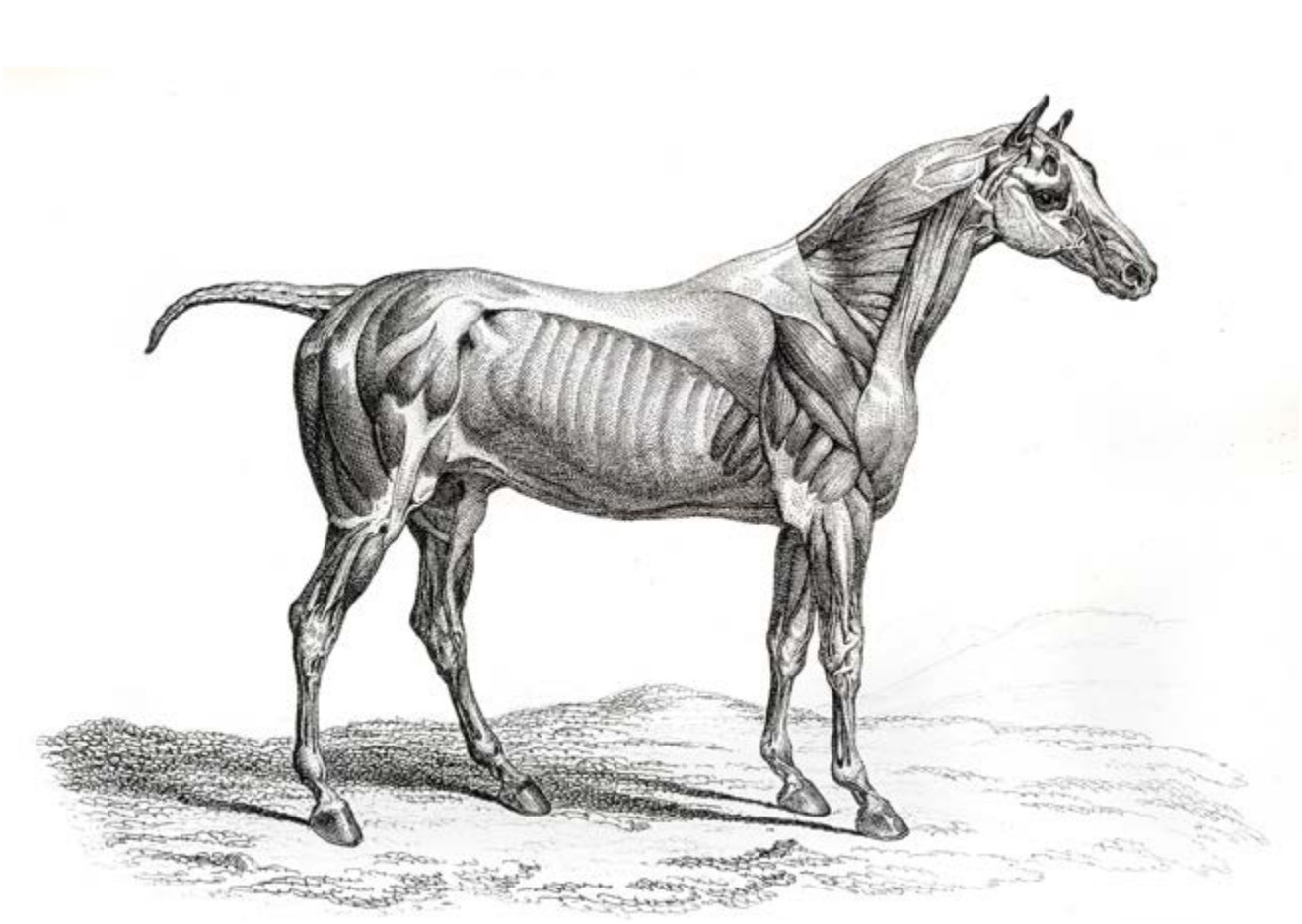
First Issue

The Journal for Equine Nutrition



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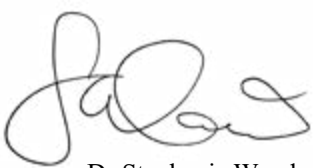
Welcome

Welcome to the Journal for Equine Nutrition, or as we like to call it, the JEN! We have developed the JEN so we can help you to do what you do best, provide your horses, ponies and donkeys with the best care. We believe in helping you develop your knowledge and understanding of equine nutrition, health, and feed science, so you can make the most appropriate decisions for the animals in your care. The JEN will include articles from our own team of nutritionists and from equine specialists working in industry and in the fields of academia, research, and veterinary science.

This first issue contains an overview of equine gastrointestinal anatomy and function by Professor Jo-Anne Murray from the University of Glasgow, which provides the foundation of understanding how we should feed and manage our horses. This is followed by a very timely article on the feeding value of grass by Dr Simon Daniels from the Royal Agricultural University. Dr Daniels picks apart why we need to account for the nutritional value of grass in our horse's diet. This is followed by an article I have written on options for managing grass intake, which again is timely as the grass is now growing. The next article opens up the subject of Boswellia, a very popular herb that has beneficial properties that we can use to support our horse's health and performance. Feedmark's Senior Nutritionist, Abigail Malone, then outlines nutritional and dietary considerations for broodmares during foaling and lactation, a very important article for those expecting new arrivals and the clip clop of tiny hooves. Talking of hooves, Abigail also provides information on the key nutrients for strong healthy hoof development in the article *Nutrition for hoof health*.

The final section is a Research Roundup which highlights the key points from the 10th European Equine Health & Nutrition Congress, which took place virtually this year. As part of Feedmark's commitment to developing products based on science and that align with the research and academic communities' views on equine health and nutrition, it was important for myself and our Senior Nutritionist to attend this congress. We not only heard the latest research, but were also part of a number of discussion sessions on developing feedstuffs to support a forage-based diet, forage options for different horses, trace element sources and supply, and managing grass intake. To find out more see *Research Roundup: Highlights from the 10th European Equine Health & Nutrition Congress*.

On behalf of the Feedmark team, I hope you enjoy reading the JEN and find the information useful. Further issues will be published periodically throughout the year and will be available digitally and in print.



Dr Stephanie Wood
Editor

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Your horse's gut: gastrointestinal structure and function

Professor Jo-Anne Murray, PhD, MSc, PgDip, PgCert, BSc (Hons), BHSII, RNutr, PFHEA, FRSB
University of Glasgow

Your horse's gut plays such an important role in maintaining health and wellbeing. The gastrointestinal tract works hard digesting feedstuffs, making essential nutrients that the horse cannot produce on its own, protecting your horse from disease, and even shaping the behaviour of your horse. Thus, it is vital to maintain gut health and to ensure you are managing your horse in a way that promotes gut health, through an understanding of the anatomy and physiology of the equine gastrointestinal tract.

OVERVIEW OF THE GASTROINTESTINAL TRACT

The horse is classified anatomically as a non-ruminant herbivore and has a digestive tract that consists of three functional regions; the stomach and the small intestine, collectively termed the foregut, and the large intestine, often referred to as the hindgut. The first section, the foregut, is similar to the pre-caecal digestive system of a monogastric animal, such as the dog, man or pig. The second section, the hindgut, is more like the rumen of a cow. The stomach of the horse contributes only eight percent to the total digestive tract weight, with a capacity of approximately eight litres in a mature 500kg horse. The small intestine is comprised of three functional regions: the duodenum, the jejunum and the ileum, which together account for around 30% of the total tract mass, but 75% of its total length. The large intestine consists of the caecum, and the large and small colons. The large intestine makes up 60% of the gastrointestinal tract volume and is proportionally the largest hindgut of any domestic animal. The hindgut of the horse is anatomically specialised to accommodate micro-organisms capable of degrading and fermenting the structural polysaccharides (fibrous fraction) of plants.

Professor Jo-Anne Murray, PhD, MSc, PgDip, PgCert, BSc (Hons), BHSII, RNutr, PFHEA, FRSB

Professor Jo-Anne Murray has a PhD in Equine Nutrition, a MSc in e-learning, a PgDip in Animal Nutrition, a PgCert in University Teaching, and a degree in Equine Science. She is Principal Fellow of the Higher Education Academy, Registered Nutritionist with the Association for Nutrition and Fellow of the Royal Society of Biology. Jo-Anne has a record of outstanding achievement in leading education. Jo-Anne led the highly acclaimed MOOC in Equine Nutrition, with over 70,000 participants from across the globe. Jo-Anne also led the first online distance learning programme in Animal Nutrition. Jo-Anne has a dual portfolio of research in animal nutrition and education. Her nutrition work is focused on: (i) improving diet digestibility; (ii) the role of diet on the gut microbiome; (iii) the gut-brain axis; and (iv) the role of supplements/feed processing on gut health, the microbiome and behaviour. Jo-Anne has established collaborations with industrial and academic partners in the UK and internationally. Jo-Anne's education research has evaluated MOOCs, mobile apps and virtual worlds. She has also evaluated horse owners' feeding practices/knowledge of nutrition and veterinarians' perceptions/knowledge of nutrition. She has published over 130 peer reviewed articles, numerous lay articles/blogs, is a journal editor (Animal) and reviewer, and invited speaker.

THE FOREGUT

The digestive process begins in the mouth. The incisor teeth (*n*=12) bite the vegetation selected by the upper lip. The pre-molar (*n*=12) and molar teeth (*n*=12) then grind the food to facilitate a reduction in particle size, whilst mixing it with saliva secreted as a direct response to chewing. Saliva appears to have little or no digestive enzyme activity in the horse, unlike many other species (Frape, 2010). However, its mucus content allows it to act as a lubricant for the passage of the feed bolus down the oesophagus into the stomach, via a process known as peristalsis, and its inorganic salt content enables it to act as a buffer to the acidic conditions present in the stomach. Chewing is such an important aspect of digestion as a) the reduction in feed particle size improves the digestibility of the nutrients in the feed and b) horses only produce saliva as a direct result of chewing and therefore if the horse is not chewing then no saliva is being produced, which can impact on the health of your horse's stomach. Horses chew four times as much, with a two-fold increase in saliva production, when eating forages compared to when eating concentrates (Meyer *et al.*, 1985).

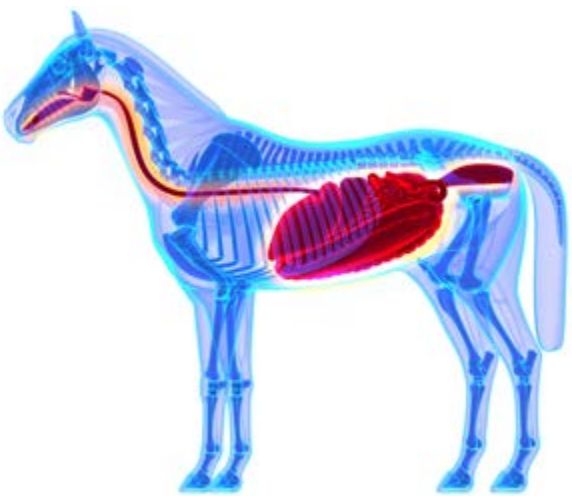

Figure 1. The average horse's gastrointestinal tract is 30m long with an enlarged hindgut developed to process a high fibre diet

The stomach of the horse has two main areas; the upper part referred to as the non-glandular region, and the lower part referred to as the glandular region. The upper part of the stomach relies on the saliva swallowed with the food, to maintain a neutral pH of between 6 and 7. The lining of this part of the stomach is susceptible to damage if the pH reduces and becomes acidic, which can result in gastric ulcers forming. The lower part of the stomach has a much lower pH (between 1.5 and 2) and the lining of this area is protected by a mucous layer. There is evidence to show that horses left for longer than 3 hours without access to forage are at greater risk of developing gastric ulcers. Horses fed large amounts of cereal grains, which take less time to chew, and lower amounts of forage, are also much more likely to develop gastric ulcers. In fact, reports suggest that as many as 85% of racehorses may have gastric ulcers (Begg & O'Sullivan, 2003). In addition, exercise can also impact on this as there can be 'splashing' of acidic contents from the lower part of the stomach to the sensitive upper part of the stomach, resulting in the formation of ulcers.

Figure 2. Fibrous foods are essential in the equine diet as they require more chewing which stimulates secretion of saliva that buffers the acidic stomach and helps to protect against gastric ulcers.

Digesta leaving the stomach enters the small intestine where it is mixed with intestinal secretions that maintain a neutral environment (pH 7) and break down fats, proteins and non-structural carbohydrates (starch and sugars).

There are a few important things to be aware of in terms of the small intestine; firstly, only the protein digested here is of direct benefit to the horse, any undigested protein travels to the hindgut and is used as a substrate by the microbiota (bacteria, fungi and protozoa, also referred to as microbes). Secondly, the horse has a limited capacity for starch digestion and any starch not digested in the small intestine will also travel to the hindgut where it will be fermented by the microbes. Moreover, cereal grains (oats,

barley, maize) need to be processed in some way otherwise the starch present in these grains is less digestible in the small intestine. Finally, the horse does not produce enzymes to break down fructan in the small intestine. Fructan is a non-structural carbohydrate (NSC) present in grass, and since this cannot be digested in the small intestine it travels to the hindgut and is used as a substrate by the microbes. High levels of starch and/or fructan entering the hindgut of the horse can disrupt the hindgut environment and elicit the onset of various disorders, such as hindgut acidosis, laminitis and colic (Bailey *et al.*, 2004). Consequently, it is recommended that no more than 1g starch per kg bodyweight is fed per meal (Harris & Dunnett, 2018), which, for a 500kg horse, is no more than 500g or 0.5kg of starch per meal. In practical terms, if concentrate feed contains 25% starch then no more than 2kg of that feed should be fed per meal.

THE HINDGUT

In contrast to the small intestine, the mucosa of the large intestine contains only mucus-secreting glands that do not produce any digestive enzymes. Instead, digestion and absorption in the hindgut is dependent on microbial fermentation of undigested feed residues leaving the small intestine. It is only in recent years that we have begun to understand more about the microbes that reside in our horse's gut. Bacteria, protozoa and fungi all inhabit the horse's gut, but bacteria appear to be present in the largest numbers and have been the primary focus of most research studies looking at gut microbes in horses.

Structural carbohydrates, i.e. those within the plant cell wall (fibrous fraction of the plant – see *Fuel or filler? What is the real nutrient content of grass for horses?*), are fermented by microbes in the hindgut as the horse lacks the endogenous enzymes required to digest these plant constituents. In fact, the hindgut is designed to digest fibre and it is when non-fibrous substrates, such as starch and fructan, enter the hindgut that problems can arise. The by-products of this fermentation process are the volatile fatty acids (VFA) acetate, propionate and butyrate, and the gases carbon dioxide (CO_2) and methane (CH_4). The VFAs are then absorbed across the gut wall and are used as an energy source by the horse (Hintz *et al.*, 1971). The microbial populations in your horse's gut are incredibly sensitive to change. Any change in diet or management can have a significant impact on microbial populations, which can lead to a disturbance in the gastrointestinal tract and an increased risk of colic (Garber *et al.*, 2020). Therefore, it is important to make any changes to the diet gradually to help maintain gastrointestinal health.

SUMMARY

- Feed a high-fibre diet, with a forage-first approach and then add in any additional feedstuffs only where required.
- Only if required, feed high-starch concentrate feeds little and often and avoid large bucket feeds of starchy foodstuffs.
- Make any changes to the diet gradually over a period of two weeks.
- Maintain a healthy weight and condition in your horse(s) and monitor on a regular basis.
- Make any management changes gradually, e.g. amount of time in the stable or at pasture.
- Consider the use of supplements that can help maintain gastrointestinal health.

REFERENCES

Bailey, S.R., Marr, C.M., & Elliott, J. (2004). Current research and theories on the pathogenesis of actute laminitis in the horse. *Equine Veterinary Journal*, 167: 129-142. doi:10.1016/S1090-0233(03)00120-5

Begg, L.M., & O'Sullivan, C.B. (2003). The prevalence and distribution of gastric ulceration in 345 racehorses. *Australian Veterinary Journal*, 81(4): 199-201. doi.org/10.1111/j.1751-0813.2003.tb11469.x

Frape, D. (2010). *Equine Nutrition and Feeding*, 4th Ed. Wiley-Blackwell, UK.

Garber, A., Hastie, P., & Murray, J.-A. (2020). Factors influencing equine gut microbiota: current knowledge. *Journal of Equine Veterinary Science*, 88: 102943. doi: 10.1016/j.jevs.2020.102943

Harris, P., & Dunnett, C. (2018). Nutritional tips for veterinarians. *Equine Veterinary Education*, 30 (9): 486-496. doi.org/10.1111/eve.12657

Hintz, H.F., Argenzio, R.A., & Schryver, H.F. (1971). Digestion coefficients, blood glucose levels and molar percentage of volatile acids in intestinal fluid of ponies fed varying forage-grain ratios. *Journal of Animal Science*, 33(5): 992-995. doi: 10.2527/jas1971.335992x

Meyer, H., Coenen, M., & Gurer, C. (1985). *Investigations of saliva production and chewing in horses fed various feeds*. Proceedings of the Nineth Equine Nutrition and Physiology Society, East Lansing, Michigan, UK: 38-41.

Fuel or filler? What is the real nutrient content of grass for horses?

Dr. Simon Daniels, PhD, PgCert, BSc (Hons), SFHEA, R.Anim.Sci, Senior Lecturer at Royal Agricultural University

As horse managers we are aware that time at grass is important for our equine companions. Grass turnout allows horses to demonstrate natural behaviours, be that of trickle feeding or social interaction. But how many horse managers really consider the nutrient content of the grass their horses are eating? I still come across people referring to fibre as "bulk" or "filler" without considering it as a source of nutrients.

PLANT NUTRIENTS

In the spring the environmental conditions are generally ideal for grass to start growing. There is moisture in the ground from the winter, the air temperature is increasing which warms the soil and the hours of daylight start to lengthen. Plants convert sunlight into soluble carbohydrates, these sugars are the energy source the plant uses for growth and they are also the energy sources our horses metabolise into useful energy (McDonald *et al.*, 2011). We are all aware that in mammals when we eat more carbohydrates than we need, we store excess either as glycogen in our muscles and liver, or as fat. Well plants have a similar mechanism whereby they store additional sugars produced via photosynthesis as water soluble carbohydrates (WSC), which includes glucose, fructose, sucrose and fructans (Undersander, 2013). Fructans are a storage molecule, a mammalian example would be glycogen whereby we convert glucose to a storage molecule to save it until we need it, then we transfer it back to glucose to metabolise it when we need it. Within the plant excess simple sugars e.g. glucose and fructose, are joined together by beta (β) glycosidic bonds to form fructan. Water soluble carbohydrates are stored within the stem of the plant as reserves for times when the plant is not producing enough sugar for growth. Fructan cannot be digested in the small intestine because mammals do not possess the enzymes needed to break the β glycosidic bonds that link the glucose and fructose molecules together. Lots of fructans entering the large intestine can be problematic to the

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Simon is a Senior lecturer at the Royal Agricultural University in Equine Science. Simon studied Equine and Animal Science at the University of Lincoln, after graduating he worked for a horse feed manufacturer as part of the nutrition team before moving on to work for the University of Liverpool on a parasitology project within the School of Veterinary Medicine. Simon went on to complete a PhD in equine anthelmintics, efficacy and effects on intestinal health with Prof Chris Proudman at the University of Surrey School of Veterinary Medicine and Science. Simon has been lecturing in higher education since 2012, and joined the RAU in 2014. Simon's research interests remain within equine gastrointestinal health and disease including both parasitology and nutrition and their effect on normal gut function. Gut health is directly influenced by diet and nutrition and therefore Simon is also interested in the management of grasslands and how both fresh and conserved forage can influence gut heath.

horse (Ince *et al.*, 2013), as fructans are readily fermented by bacteria in the horse's hindgut, specifically by "sugar loving" saccharolytic bacteria (Shirazi-Beechey, 2008). Fructan is converted into a volatile fatty acid (VFA) that feeds into the glucose pathway, but it is also converted into lactate. The production of significant amounts of lactate decreases the pH in the horse's hindgut ecosystem, altering the conditions which the fibre loving bacteria that reside here need to survive (Daly *et al.*, 2012) (see *Your horse's gut: gastrointestinal structure and function* for more information on the equine digestive tract and importance of the hindgut). Practically we see this on a scale, from horses producing loose droppings at the subtle end of the scale, to colic and laminitis at the severe end, and thus stability of microbiota in the horse's hindgut is essential for horse health. This is why we avoid grazing laminitic animals when fructan in the grass is likely to be high.

As the growing season continues the grass continues to grow and the leaves become more mature. We are all aware that fresh spring leaves tend to flop to the ground but if we leave grass to grow e.g. for hay, then as it matures it stands upright. As the plant matures the cell wall increases in thickness to give the plant structure (Cuddeford, 1996). We refer to this cell wall as structural carbohydrates, which are the elements of the plant which make up the fibre content. Fibre is essential for the horse's diet and fibre digestibility is also influenced by the grass growth cycle as not all fibres are digestible. The plant cell wall which allows the plant to stand tall is made of lignin which is found in all plants but unfortunately it cannot be digested, therefore as the plant matures and lignin increases, the digestibility decreases (Cuddeford, 1996).

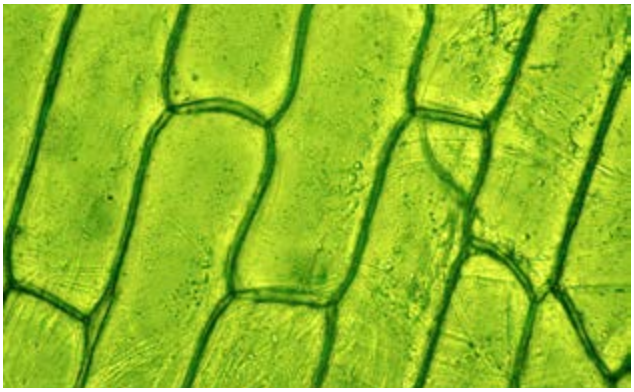

Figure 1. Plant cells under magnification, showing the insoluble, fibrous cell wall (dark green outline) and soluble inner cell contents

Fibre is formed by joining β glucose molecules together, similar to forming fructans, but in this case in much longer chains forming the structural carbohydrate cellulose (McDonald *et al.*, 2011). To digest fibre we need to break the glycosidic bonds between these β glucose molecules to be able to make use of these carbohydrates. However, mammals do not possess the enzymes, principally cellulase, needed to break down the bonds in the β glucose molecules which form cellulose, in the same way that they cannot digest fructan (Frape, 2010). However, microbiota that reside in the horse's hindgut and in the rumen of cows and sheep, do produce cellulase, meaning these microbiota can break down fibre through fermentation. The younger the plant is in the growth cycle the more fibre can be digested (Cuddeford, 1996). Of the cell wall contents the most digestible component is hemicellulose. Other digestible fibre sources are pectins which are found between two plant cells and act as glue to stick cells together.

Plant protein is found inside the plant cells, and is made up of sequences of amino acids. Some amino acids can be synthesised within the body (termed non-essential amino acids) but others must be sourced within the diet (termed essential amino acids) and are essential nutrients for normal body function. Lysine is an essential amino acid that is also the first limiting amino acid, meaning it is the first to become deficient. Therefore, when considering protein content in the diet we have to consider if we can meet the horse's amino acid requirements from our grass. The next consideration for protein within grass is the digestibility, as the horse can only make use of protein that is digested and absorbed within the small intestine (Frape, 2010). As the plant matures and the cell wall becomes more lignified then the amount of protein digestion in the small intestine is reduced. In more mature lignified grass the protein is liberated from the plant cells in the horse's hindgut where billions of microbiota ferment the plant material. However protein that is digested in the hindgut is not bioavailable to the horse, instead the microbiota make use of this protein themselves. So as the growing season progresses the protein digestibility of mature grass within the horse decreases.

The fat content of grass is limited, but fat is present consisting of waxes and includes essential omega-3 fatty acids. The vitamin and mineral content will be influenced by the soil and the management of the grass, but much of the major mineral requirement of horses should be covered by grass (Cuddeford, 1996).

NUTRIENT REQUIREMENTS OF HORSES

If initially we assume the nutrient requirements at maintenance for a mature 500 kg animal are approximately 70 mega joules (Mj) of digestible energy (DE) per day, a breakdown of the key nutrient requirements can be seen in table 1 below.

Table 1. Key nutrient requirements of a 500kg horse at maintenance

Nutrient	500kg Horse
DE (Mj)	69.68
CP (g)	630
Lys (g)	27
Ca (g)	20
P (g)	14
Na (g)	10
Cl (g)	40
K (g)	25

DE: Digestible energy, CP: Crude protein, Lys: Lysine, Ca: Calcium, P: Phosphorus, Na: Sodium, Cl: Chloride, K: Potassium.

The energy content of grass will obviously be variable depending on time of year, weather conditions, location, and management, but for meadow pasture the DE content is approximately 8-10 Mj/kg on a dry matter (DM) basis. However, some ryegrasses with high water soluble content can be up to 14 Mj/kg DM. We generally assume that on a dry matter basis that horses at pasture full time will eat over 15 hours around 1kg of dry matter per hour. We work to the basis that grass is roughly 20% dry matter and therefore the fresh matter intake of grass per day will be considerably greater as we allow for the moisture content. Working on those assumptions, the average 500kg horse can consume 135 Mj on the basis of eating 15kg dry matter. On the assumption that the digestibility of good pasture is around 60%, on average we exceed the daily energy requirement.

The crude protein (CP) content varies by season, being approximately 300g/kg DM in the spring, 100-140g/kg DM in the summer, 140-200g/kg DM in the autumn and less than 100g/kg DM in the winter. Applying this to the scenario above, in theory the crude protein requirement would be met all year. However this does not factor in protein quality, availability, digestibility in the small intestine nor the amino acid profile. Working to the digestibility profile above (60%), when there is less than 120g/kg of CP available in the grass and the grass is mature, we are unlikely to meet the daily requirement of our scenario animal as a proportion of this protein will be degraded in the hindgut. Equally, the digestibility will decrease as the plant matures as the protein become less bioavailable. Minerals and trace minerals in well managed grass should meet the nutrient requirements with possible slight deficiencies in copper and selenium by 2 and 0.5 mg/kg respectively, but this will depend on the individual soil profile.

PASTURE SUITABILITY

So theoretically we should be able to meet the maintenance nutrient requirement of horses from pasture alone, although this will depend on the individual animal's requirements. If we consider a Thoroughbred racehorse then the nutrient requirement will be much higher than that of a native pony type, even at maintenance. We also need to consider how we manage our grass as agricultural practices for cattle often produce grass with too much WSC for our horses (Longland, 2012). Sometimes horse managers can be guilty of neglecting pastures and they become "horse sick" (Figure 2). It is important that we manage our grass to avoid this. Many of the weeds flourish because the grass is over grazed, not fertilised and the soil pH is not optimum. Many horse managers worry about using fertiliser on their grass as they do not want excess grass growth. However, the grass plants need both phosphorus and potassium for good root development. If the roots are deep and well developed, they will seek water and nutrients from further into the ground, helping the plants become resilient to "horse traffic". Shallow rooted plants will not thrive and it is easier for poaching to occur, therefore it is important to feed the roots with a fertiliser appropriate for your pasture type and requirements.

Over grazing grass down to very fine stubble also causes the plant stress. To aid recovery the plant will store more WSC e.g. fructans which help it recover. This can be problematic for weight management and animals prone to laminitis (Watts, 2010). This is the same at times of drought and frost, and is the reason why you may have come across advice not to graze frosty grass.

Figure 2. Allowing fields to be extensively grazed enables weeds to take over and the pasture to become 'horse sick', reducing its value as a feed source

Often with horses we have grazing extremes, either poorly managed grasslands that become horse sick, or grasses that are managed for agricultural purposes e.g. cattle. High productivity cows are often managed on high WSC pastures to ensure plenty of energy is available for growth or milk production. These pastures tend to be unsuitable for horses who do not need high WSC diets. The problems are greatest with our ponies and cob types which have been recorded eating up to 5% of their body weight per day in dry matter, in comparison to horses who at maximum can eat 3% of their body weight per day in dry matter. Going back to cows briefly, a dairy cow needs approximately 62 Mj of energy a day for maintenance, yet for milk production she needs three times that for a low milk yield, or five and a half times that for a high yield. So our cob type, needing approximately 70 Mj DE per day for maintenance and grazing 5% of its body weight in dry matter, can consume four times its daily maintenance energy requirement per day. This is why grazing designed for cattle does not work for horses, especially good doers and ponies, and it is easy to see how they can become obese by eating four times their maintenance energy requirement per day! Another management problem with native types is they are designed to store reserves for the winter, therefore they gain weight in the summer to lose in the winter. However the use of rugs, feeding concentrates and stabling mean that these native types and good doers just continually gain weight.

TAKE HOME MESSAGE

There is huge potential in our grass, however sometimes it can under deliver on essential minerals and nutrients such as protein, and over supply energy contributing to equine obesity. It is really important that we manage our grass for horses, so we can have healthy pasture and healthy horses. Making use of mineral licks/supplements or balancers can be a way of ensuring you provide the protein and minerals without providing additional calories, and as for weight management of horses, well that is a whole other topic in itself!

REFERENCES

Bott, R.C., Greene, E.A., Koch, K., Martinson, K.L., Siciliano, P.D., Williams, C., Trottier, N.L., Burk, A., & Swinker, A. (2013). Production and Environmental Implications of Equine Grazing. *Journal of Equine Veterinary Science*. 33: 1031-1043. doi.org/10.1016/j.jevs.2013.05.004

Cuddeford, D. (1996). *Equine Nutrition*. The Crowood Press Ltd.

Daly, K., Proudman, C. J., Duncan, S.H., Flint, H.J., Dyer, J., & Shirazi-Beechey, S. (2012). Alterations in microbiota and fermentation products in equine large intestine in response to dietary variation and intestinal disease. *British Journal of Nutrition*, 107(7): 989-995. doi:10.1017/S0007114511003825

Frape, D. (2010). *Equine Nutrition and Feeding*, 4th Ed. Wiley-Blackwell, UK.

Ince, J.C., Longland, A.C., Moore-Colyer, M.J.S., & Harris, P.A. (2013). *In vitro* degradation of grass fructan by equid gastrointestinal digesta. *Grass and Forage Science*, 69(3): 514-523. https://doi.org/10.1111/gfs.12061

Longland, A.C. (2012). Nutritional assessment of forage quality. In: Saastamoinen M., Fradinho M.J., Santos A.S., Miraglia N. (eds) *Forages and grazing in horse nutrition*, vol 132. Wageningen Academic Publishers, Wageningen.

McDonald, P., Edwards, R.A., Greenhalgh, J.D.F., Morgan, C.A., Sinclair, L.A. & Wilkinson, R.G. (2011). *Animal Nutrition*, 7th Ed. Pearson Education Ltd.

Shirazi-Beechey, S.P. (2008). Molecular insights into dietary induced colic in the horse. *Equine Veterinary Journal*, 40(4): 414-421. doi:10.2746/042516408X314075

Undersander, D. (2013). Grass Varieties for Horses. *Journal of Equine Veterinary Science*, 33: 315-320. doi.org/10.1016/j.jevs.2013.03.008

Watts, K. (2010). Pasture management to minimise the risk of equine laminitis. *Veterinary Clinics of North America: Equine Practice*, 26(2): 361-369. doi.org/10.1016/j.cveq.2010.04.007

Managing our horse's grass intake

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As you might expect, the amount of time our horses spend in the field varies with the seasons, with more horses living out in summer as the days get longer and the weather and ground conditions improve, and more horses being completely stabled in winter primarily to avoid fields becoming poached (Ireland *et al.*, 2011). Regardless of the time of year, most owners report giving their horses daily access to pasture, even if only for a few hours (Ireland *et al.*, 2011; Wylie *et al.*, 2013). Time in the field allows horses to move freely, interact with their surroundings, interact with other horses visually if in separate fields, and physically if they can touch, and to perform grazing behaviour that is so important to them for maintaining mental and physical health (see *Your horse's gut: gastrointestinal structure and function*). As discussed in the article *Fuel or filler? What is the real nutrient content of grass for horses?* time in the field also supplies nutrients and should be accounted for when developing and managing your horse's diet. Accounting for the energy (calories), protein, fatty acids, vitamins, and minerals horses obtain from grass is not always the primary consideration by owners, as it is easy to view the field as a place where horses exercise and enjoy time being a horse, and not as a self-service buffet. Not accounting for grass as a source of nutrients and energy can lead to horses consuming an unbalanced diet that affects their condition, health and performance.

Accounting for the grass our horses consume is not straight forward. Energy and nutrient content change with grass stage of growth, and determining how much your horse eats when in the field is particularly challenging. The only real way of knowing the nutrient content of the specific grass your horse is eating is to analyse for its nutrient content. Commercial premises producing high value horses are more likely to undertake grass nutrient analysis, although analysis of grazing for horses is still not common practice. One potential reason for limited testing of grass is that the results gained are specific to the sample taken at a certain point in time, so may not be applicable to all parts of your pasture or to grass at a different growth stage (Martinson *et al.*, 2017). Despite these limitations, testing for nutrient content is advised as it is better than not having any information on the grass your horse is eating. Determining how much grass your horse eats when turned out is the other challenge making it difficult to account for grass intake in your horse's diet. In the research setting, measuring the amount of grass before horses graze and then again after grazing, enables estimates of how much grass is consumed (Martinson *et al.*, 2017). This method is relatively straight forward but is only an estimate due to sampling small sections of grass, meaning variations in grass cover are not accounted for. This method also does not account for the selective grazing behaviour of horses who will eat certain plant species and completely ignore others (Archer, 1973). It is also only suitable for estimating intake over a short period of time (hours) as it does not account for grass growth over the grazing period.

A more accurate estimate of grass intake can be gained from information on the digestibility (amount of nutrients absorbed by the animal) of the grass consumed and the amount of faeces produced. Markers are used to gain such information, and are substances that are indigestible to the horse, meaning they can be tested for in the faeces (Dove & Mayes, 1991; Martinson *et al.*, 2017). The use of markers is generally more accurate than measuring grass before and after grazing, however it is only suitable for use in the research setting due to the requirement for chemical markers and laboratory equipment.

Due to the difficulties in determining our horses' grass intake, and the potential for grass to trigger laminitis in some equids, we need practical methods to account for energy and nutrients gained from grass. We also need practical methods to manage grass intake, whether this is limiting the amount of grass consumed for those animals prone to laminitis, insulin dysregulation and weight gain,

or optimising grass intake for growing animals and those needing to gain weight. For healthy horses, the easiest way of accounting for grass intake in the diet is to monitor their weight and fat stores. Monitoring body weight and fat stores by regularly weigh taping and fat scoring your horses is straight forward, quick and non-invasive, and indicates if more or less energy is required (Figure 1). If all other parts of your horse's diet, exercise and management remain the same and they are gaining weight then they must be gaining more energy from the grass, and vice versa if they are losing weight. You can then review your horse's diet to identify what changes are needed to enable them continued access to the field whilst keeping them at a healthy body weight. Reviewing the diet as a whole (grass, preserved

Figure 1. Regularly assessing your horse's weight and fat stores is important for determining if their diet or management requires adjustment, with weigh tapes offering an easy way of estimating body weight

forage, concentrate feeds and supplements) is important as fat scoring does not account for intake of other nutrients, although it does provide an indication of the potential nutritional quality of your grass. Ideally you want to utilise the grass as a nutrient source and minimise the amount of concentrate feed you are providing as this will help to maintain gastrointestinal and mental health, and is one of the cheapest forms of feed available. One of the easiest ways of ensuring your horse is receiving all the nutrients it requires is to feed a vitamin and mineral supplement (concentrated vitamins and minerals) or a balancer (vitamins, minerals and protein source), as these are low in starch and sugars and can be fed either on their own if pelleted, or with a small amount of chaff if powdered.

LIMITING GRASS INTAKE

Many owners find they need to limit the amount of grass their horse or pony consumes due to them being prone to weight gain or susceptible to metabolic issues such as laminitis or insulin dysregulation. How best to control the amount of grass your horse eats will depend on the facilities available to you and the amount of flexibility you have using those facilities. The main methods of limiting grass intake are;

1. reduce the amount of time with access to grass
2. reduce the amount of grass your horse has access to
3. reduce your horse's ability to consume the grass

1) Reduce the amount of time with access to grass:

Reducing the amount of time your horse has access to grass requires them to spend more time in an alternative environment. For many owners the only other place they can keep their horses is in the stable. Ideally, we want to reduce the stabling period as it reduces their physical movement and time they can interact with other horses, increases their exposure to stable dust which can negatively impact respiratory health (Hotchkiss, 2019), and increases bedding and forage costs. There are times when horses have to be stabled rather than out in the field, e.g. due to ill-health, injury, or to reduce exposure to biting midges and flies that irritate the skin, but we would ideally not stable them for extended periods of time to just reduce grass intake. An alternative is to provide access to a dry lot, or fenced area with an alternative ground surface. Such setups prevent grazing whilst allowing movement, social interaction, and fresh air. If using such a setup, access to water and shelter are still required and it is recommended to provide a form of low energy preserved forage so horses can continue trickle feeding but without consuming too many calories.

Reducing time in the field may not always lead to reduced grass intake. The amount of grass consumed, measured as dry matter intake (DMI), is a result of bite rate

(number of bites per minute) and bite size (amount of grass per bite), with these factors being influenced by animal size and the amount of grass available (Fleurance *et al.*, 2009). Equids respond to variations in grass availability by increasing or decreasing these bite parameters, with a balance being required to maintain DMI. When ample grass is available larger bites can be taken, however these require more chewing and can result in a lower bite rate, whereas when grass availability is limited, smaller, more frequent bites can be taken (Naujeck & Hill, 2003; Edouard *et al.*, 2009). As bite rate increases, selectivity decreases, meaning that when food resources are limited equids have a feeding strategy of maintaining DM and energy intake, rather than selecting for higher nutrient plants (Friend & Nash, 2000; Wood *et al.*, 2012). This feeding strategy leads to variations in individual nutrient intakes and their balance within the diet.

When limiting grazing time studies have shown that horses, ponies, and donkeys increase bite rate and/or bite size, leading to a faster DMI. Ince *et al*. (2011) restricted ponies to 3-hours grazing per day over a 6-week period and found that the amounts of grass consumed increased over the six weeks, with ponies consuming almost double the amount they consumed at the start of the study. These results indicate that the ponies became accustomed to the management routine and short grazing time, increasing their intake rate to maximise the amount of grass they could eat. Similar results were reported by Glunk *et al.* (2013) restricting mature horses to either 3-, 6-, 9- or 24-hours grazing. These authors found that intake rate increased with decreasing grazing time, being fastest when horses had three hours grazing time and slowest when they had 24-hour access to grass. This faster DMI allows equids to compensate for shorter grazing periods, potentially neutralising any effect of reduced grazing time, although this is dependent on the amount of grass available. In the study by Glunk *et al.* (2013), the amount of grass available prevented horses compensating for the shorter grazing times, leading to significantly less grass being eaten when restricted to six hours grazing or less, compared to when allowed 24 hours access. In a study using donkeys where grass availability was extremely limited, donkeys restricted to 8-, 12- and 23-hours grazing access ate similar amounts of grass as there was no benefit to donkeys grazing for longer due to such sparse pasture. When grass availability increased the donkeys with 23-hours access were at an advantage, able to consume more than those with 12- or 8-hours grazing (Wood *et al.*, 2012). Such results do not mean that restricting time in the field is unsuitable for limiting grass intake, but they do show that the effect of grazing time on your horse's intake may not be easy to predict and will be affected by the amount of grass available and your individual horse's response. When the amount of grass available is limited, bite size and bite rate can only increase by so much, meaning that in these circumstances they cannot compensate for reduced time at grass, leading to a lower DMI from grass whilst allowing all the benefits of time in the field previously discussed.

Overnight grazing

Another option available to owners is to allow access to pasture overnight and to stable or keep horses on dry lots during the day. Equids graze less intensively overnight (Doreau *et al.*, 1980; Wood, 2010) so only turning out overnight may help to reduce intake and is more suitable for some animals affected by biting insects or sunburn. The amount of grass available should still be considered in these circumstances as some equids will adapt to a night grazing routine and simply eat an equivalent amount as they would during the day.

2) Reduce the amount of grass your horse has access to:

An alternative to restricting the amount of time your horse has access to grass is to influence the amount of grass. Shorter grass tends to have lower herbage mass (g DM/hectare) than taller grass, however taller grass is more fibrous and of lower nutritional value, meaning there is no simple answer to what length grass is optimum for horses. The height of grass has been shown to influence bite parameters, and therefore grass intake, by horses, ponies and donkeys. When grazing shorter grass, smaller, more frequent bites that require less chewing are utilised, allowing equivalent amounts to be consumed as when grazing taller grass (McMeniman, 2003; Fleurance *et al.*, 2010). Increased time spent grazing combined with increased bite rate can compensate for shorter grass, meaning that limiting

one, or both, of these compensatory options (grazing time or grass height) has the potential for reducing grass intake. Harrison & Murray (2016) found that limiting ponies to very short grass (1-2cm) did effectively limit the amount of grass they could consume, however having such short grass may damage the pasture and underlying soil structure.

Increased stocking density

Increasing the number of animals on the grass is another option for decreasing herbage mass per animal (g DM/ animal), although there are a number of factors to consider before choosing this option. With an increased number of equids in a field there will be increased competition for food, water and shelter resources. The increased competition for food is positive if wanting to reduce grass intake, however increased competition for water and shelter will increase animal interactions and potentially the risk of injury (Owen *et al.*, 2012). You also need to ensure that there are no harmful plants, such as ragwort or bracken, that could be consumed if horses become hungry and seek alternative food sources. The effect on pasture quality should also be considered, as over-grazing can cause weeds to proliferate and takeover. Increased weeds are also seen in areas where horses defecate, leading to a greater proportion of the field being left ungrazed due to weeds and toilet areas, which also reduce pasture quality. A final consideration is the increased potential for parasite transmission between animals. Reducing parasite burdens require the life cycle of the parasite to be broken (Corbett *et al.*, 2014; Rendle *et al.*, 2019). This is achieved by identifying infected animals and providing effective treatment, and by removing faeces from the pasture, which can be difficult when large numbers of equids are in the same field.

Grazing with non-equine species such as sheep, overcomes some of these issues whilst reducing herbage mass per animal. Sheep and horses tend to graze different parts of the field, resulting in a more uniform pasture. Sheep and horses are also less likely to cause injury to each other, however fencing required to keep sheep in the field is usually not safe for horses due to the risk of their legs becoming caught. Grazing with sheep also increases the risk of liver fluke in equines (Howell *et al.*, 2020) therefore it is important to assess and manage this risk.

Strip grazing

Controlling the amount of fresh, ungrazed pasture your horse accesses daily using strip grazing is a practical option for many owners, being relatively quick, simple and cheap to setup using electric fencing. Strip grazing using a single moving fence (Figure 2, Setup A) limits the amount of ungrazed grass your horse can eat, however the total grazing area increases in size over time. As animals preferentially graze the fresh grass, the grass in the remainder of the field

Figure 2. Options for strip grazing equids. Setup A uses a single, lead fence. Setup B uses a lead fence and a back fence to maintain the same size grazing area.

has opportunity to grow. This can lead to the beneficial effects of strip grazing being reduced as the overall herbage mass per animal increases. Strip grazing using two fences (Figure 2, Setup B) has a lead fence that moves to allow access to fresh, ungrazed grass, and a back fence that is moved the same distance as the lead fence, that keeps the grazing area size the same. Using two fences not only helps to control herbage mass per animal, but also enables areas of the field to be rested without having to remove animals from the area completely.

Over a 28-day period, Longland *et al.* (2021) studied the effect of strip grazing on grass intake by ponies with 23-hours access to grass. The study compared the effect of strip grazing using a single lead fence (setup A), strip grazing using a lead and a back fence (setup B), and no strip grazing where ponies had access to a grazing area of equivalent size and herbage mass. Ponies consumed significantly less grass when managed using the strip grazing systems compared to those with no strip grazing, despite the same overall grazing area. The lowest intakes were recorded for ponies managed with a lead and back fence due to them having a smaller grazing area and lower herbage mass per animal. In the first two weeks of the study the ponies in the strip grazing groups grazed all parts of the fresh grass, leaving very little ungrazed grass. This indicated they were not selectively grazing and were focusing on consuming whatever fresh grass they could access. This was opposite to the ponies with access to the whole pasture area who selectively grazed, most likely at a slower rate. A concern by some owners is that horses, ponies, and donkeys managed using strip grazing, excessively gorge on the fresh grass once access is provided. Such a concern is valid as sudden intakes of fresh, lush grass can lead to gastrointestinal upset. Research by Dowler *et al.* (2012) who limited adult horses to 8-hours grazing per day and monitored grass DMI over this period, found that the rate of grass intake was greatest (almost double) in the first four hours of grazing than in the second four hours of grazing. If utilising strip grazing, it is worth considering when to allow access to the fresh pasture. If practical, offering fresh grass after animals have already been grazing for several hours, or overnight if managed with 24-hour grazing, may help to reduce this sudden rapid intake. What was very positive in the study by Longland *et al.* (2021) is that both methods of strip grazing lead to ponies maintaining a relatively stable body weight over the study period compared to ponies with access to the whole grazing area who gained weight and increased fat stores. Such results show that strip grazing is a useful option for limiting grass intake whilst allowing access to the field.

3) Reduce your horse's ability to consume the grass:

Reducing your horse's ability to consume grass can be achieved by using grazing muzzles (Figure 3). Various muzzle designs are available, all aiming to reduce your horse's bite size, although many equids also seem less motivated to graze when they are wearing a grazing muzzle, suggesting that the effort required to eat may not be worth the small amount of grass gained. The effectiveness of grazing muzzles on reducing grass intake ranged from 83% in ponies grazing over a 3-hour period (Longland *et al.*, 2011) to 30% in horses grazing over a 4-hour period (Glunk *et al.*, 2014). The differences between these figures reflects the differences in methods used to estimate intakes and differences in grass height. In the study by Longland *et al.* (2011) the ponies were grazing grass 8-15cm tall, whereas in the study by Glunk *et al.* (2014) the grass was

Figure 3. Muzzles are one option for limiting the amount of grass horses can consume whilst allowing them time in the field

15-20cm tall. It is thought that grass that is too short cannot reach through grazing muzzles, leaving animals frustrated and likely to dig up short pastures in an attempt to eat something. In contrast, grass that is too long can be difficult to sever and chew when wearing muzzles, potentially reducing intake. The form of the grass can also influence the

effectiveness of muzzles. Grasses that grow upright easily poke through the muzzle giving the animal something to eat, whereas grasses that have a wider growth pattern are not as easily accessible. Muzzles seem most appropriate for use when grass is 3-20cm tall, although this will vary with grass species and your individual horse, pony or donkey's response.

All of these factors need considering when deciding whether to use grazing muzzles. They can certainly help to reduce grass intake however they should not be left on all day, and therefore horses may simply compensate for reduced intake due to being muzzled, by eating rapidly when unmuzzled (Longland *et al.*, 2016; Davis *et al.*, 2020). Such compensatory responses indicate that grazing muzzles are helpful in managing grass intake if used alongside other practices, such as limiting grazing time or strip grazing.

Animals must be acclimatised to wearing muzzles and checks made that they know how to drink otherwise they risk dehydration. Some animals refuse to drink whilst wearing muzzles which is one reason they should not be worn 24-hours a day. As previously mentioned, some equids are reluctant to even try to graze when wearing a muzzle and spend their time just standing in the field. Whilst this is preferable to standing in a stable, long periods of time without consuming any food are not advised.

OPTIMISING GRASS INTAKE

The phrase 'Doctor Green' relates to the nutrients grass can supply to our horses and the beneficial effects of these nutrients. As discussed in *Fuel or filler? What is the real nutrient content of grass for horses?* grass can be an excellent source of nutrients, and for some horses, is the food that makes them look and feel at their best. For these animals, the main aim is optimising intake and balancing the diet.

Optimising intake is about correct pasture management. Ensuring there is adequate herbage mass per animal and appropriate grass species for the type of animal, type of soil and weather conditions is important. Discussing your specific requirements with an agronomist with an interest in equine pastures is the best option for achieving a suitable pasture that will have longevity. More immediate actions you can take are to ensure you provide appropriate shelter from inclement weather and the sun. Flies and midges are also deterred from entering dark areas so a shaded area will help to reduce irritation from biting insects. Clean, fresh water with enough access space for multiple horses at once is also essential.

One of the most important actions you can take is to create a clean grazing area by regularly removing faeces from the field. This has multiple benefits, including increasing grazing area per animal, breaking the parasite

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Stephanie has many years' experience managing horses in both a private and professional capacity. During her time caring for different horses she developed a keen interest in nutrition which lead her to gain her undergraduate degree in Equine Science from Aberystwyth University, followed by a PhD in Equine Nutrition from the Royal (Dick) School of Veterinary Studies at the University of Edinburgh. These academic achievements are recognised in her certifications as a Registered Animal Nutritionist and Registered Animal Technologist.

Stephanie has a passion for helping others to learn and understand which was utilised in her positions as Senior Equine Technologist where she developed training and educational material for the equine industry, and as Senior Lecturer where she tutored the next generation of equine professionals. Stephanie's passion for helping others combined with her hands-on industry experience and technical knowledge enable her to support owners with practical advice and guidance in her role as Director of Science and Nutrition at Feedmark.

life cycle, reducing weed development and not attracting flies. It is important that collected faeces are removed from the field and not piled in the field corner as this simply concentrates the issues of flies, parasites, and weeds in one place. By creating a pleasant environment for your animals to graze they are more likely to be settled and enjoy being in the field, taking their time to forage and exhibit their natural grazing behaviour.

SUMMARY

Grass is an extremely useful resource for most equids so long as the amount consumed is managed to match the individual animal's requirements. For some equids this may mean reducing time in the field and increasing time in a dry lot, arena, or stable, whilst for others a grazing muzzle is the perfect tool for limiting grass intake. For those who seem to blossom when Doctor Green is here then providing clean, hygienic grass should be the focus. When not grazing, providing a suitable preserved forage will enable trickle feeding to continue and optimise gastrointestinal and mental health. A vitamin and mineral supplement or balancer further supports health and ensures optimum nutrient intake.

REFERENCES

Archer, M. (1973). The species preferences of grazing horses. *Journal of the British Grassland Society*, 28: 123-128. doi.org/10.1111/j.1365-2494.1973.tb00732.x

Corbett, C.J., Love, S., Moore, A., Burden, F.A., Matthews, J.B., & Denwood, M.J. (2014). The effectiveness of faecal removal methods of pasture management to control the cyathostomin burden of donkeys. *Parasite & Vectors*, 7:48. doi:10.1186/1756-3305-7-48

Davis, K.M., Iwaniuk, M.E., Dennis, R.L., Harris, P.A., & Burk, A.O. (2020). Effects of grazing muzzles on behavior and physiological stress of individually housed grazing miniature horses. *Applied Animal Behaviour Science*, 231: 105067. doi.org/10.1016/j.applanim.2020.105067

Doreau, M., Martin-Rosset, W., & Petit, D. (1980). Activités alimentaires nocturnes du cheval au pâturage. *Annales de Zootechnique*, 29: 299-304.

Dove, H., & Mayes, R.W. (1991). The use of plant wax alkanes as marker substances in studies of the nutrition of herbivores: A review. *Australian Journal of Agricultural Research*, 42: 913-952. doi.org/10.1071/AR9910913

Dowler, L.E., Siciliano, P.D., Pratt-Phillips, S.E., & Poore, M. (2012). Determination of Pasture Dry Matter Intake Rates in Different Seasons and Their Application in Grazing Management. *Journal of Equine Veterinary Science*, 32: 85-92. doi:10.1016/j.jevs.2011.06.006

Edouard, N., Fleurance, G., Dumont, B., Baumont, R., & Duncan, P. (2009). Does sward height affect feeding patch choice and voluntary intake in horses? *Applied Animal Behaviour Science*, 119:219-228. doi:10.1016/j.applanim.2009.03.017

Fleurance, G., Duncan, P., Fritz, H., Gordon, I.J., & Grenier-Loustalot, M.-F. (2010). Influence of sward structure on daily intake and foraging behaviour by horses. *Animal*, 4: 480-485. doi:10.1017/S1751731109991133

Fleurance, G., Fritz, H., Duncan, P., Gordon, I.J., Edouard, N., & Vial, C. (2009). Instantaneous intake rate in horses of different body sizes: influence of sward biomass and fibrousness. *Applied Animal Behaviour Science*, 117: 84-92. doi.org/10.1016/j.applanim.2008.11.006

Friend, M.A., & Nash, D. (2000). *Pasture intake by grazing horses*. Canberra, Australia, Rural Industries Research & Development Corporation.

Glunk, E.C., Pratt-Phillips, S.E., & Siciliano, P.D. (2013). Effect of Restricted Pasture Access on Pasture Dry Matter Intake Rate, Dietary Energy Intake, and Fecal pH in Horses. *Journal of Equine Veterinary Science*, 39: 421-426. doi.org/10.1016/j.jevs.2012.07.014

Glunk, E.C., Sheaffer, C.C., Hathaway, M.R., & Martinson, K.L. (2014). Interaction of Grazing Muzzle Use and Grass Species on Forage Intake of Horses. *Journal of Equine Veterinary Science*, 34: 930-933. doi.org/10.1016/j.jevs.2014.04.004

Harrison, R., & Murray, J.M.D. (2016). A preliminary study of grazing intakes of ponies with and without a history of laminitis. *Livestock Science*, 186: 2-5. doi.org/10.1016/j.livsci.2015.08.012

Hotchkiss, J.W. (2019). Equine asthma: managing the environment. *UK-Vet Equine*, 3(3). doi.org/10.12968/ukve.2019.3.3.78

Howell, A.K., Malalana, F., Beesley, N.J., Hodgkinson, J.E., Rhodes, H., Sekiya, M., Archer, D., Clough, H.E., Gilmore, P., & Williams, D.J.L. (2020). Fasciola hepatica in UK horses. *Equine Veterinary Journal*, 52: 194-199. doi: 10.1111/evj.13149

Ince, J., Longland, A.C., Newbold, J.C., & Harris, P.A. (2011). Changes in proportions of dry matter intakes by ponies with access to pasture and haylage for 3 and 20 hours per day respectively, for six weeks. *Journal of Equine Veterinary Science*, 31: 283. doi.org/10.1016/j.jevs.2011.03.106

Ireland, J.L., Clegg, P.D., McGowan, C.M., McKane, S.A., & Pinchbeck, G.L. (2011). A cross-sectional study of geriatric horses in the United Kingdom. Part 1: Demographics and management practices. *Equine Veterinary Journal*, 43(1): 30-36. doi:10.1111/j.2042-3306.2010.00145.x

Longland, A.C., Barfoot, C., & Harris, P.A. (2011). The effect of wearing a grazing muzzle vs not wearing a grazing muzzle on pasture dry matter intake by ponies. *Journal of Equine Veterinary Science*, 31 (5-6): 282–283. doi.org/10.1016/j.jevs.2011.03.105

Longland, A.C., Barfoot, C., & Harris, P.A. (2016). Efficacy of Wearing Grazing Muzzles for 10 Hours per Day on Controlling Bodyweight in Pastured Ponies. *Journal of Equine Veterinary Science*, 45: 22-27. doi.org/10.1016/j.jevs.2016.04.015

Longland, A.C., Barfoot, C., & Harris, P.A. (2021). Strip-grazing: Reduces pony dry matter intakes and changes in bodyweight and morphometrics. *Equine Veterinary Journal*, 00: 1–8. doi: 10.1111/evj.13416

Martinson, K.L., Siciliano, P.D., Sheaffer, C.C., McIntosh, B.M., Swinker, A.M., & Williams, C.A. (2017). A Review of Equine Grazing Research Methodologies. *Journal of Equine Veterinary Science*, 51: 92-104. doi.org/10.1016/j.jevs.2017.01.002

McMeniman, N.P. (2003). *Pasture intake by young horses*. Canberra, Australia, Rural Industries Research & Development Corporation.

Naujeck, A., & Hill, J. (2003). Influence of sward height on bite dimensions of horses. *Animal Science*, 77: 95-100. doi:10.1017/S1357729800053698

Owen, K.R., Singer, E.R., Clegg, P.D., Ireland, J.L., & Pinchbeck, G.L. (2012). Identification of risk factors for traumatic injury in the general horse population of north-west England, Midlands and north Wales. *Equine Veterinary Journal*, 387: 143-148. doi:10.1111/j.2042-3306.2011.00387.x

Rendle, D., Austin, C., Bowen, M., Cameron, I., Furtado, T., Hodgkinson, J., McGorum, B., & Matthews, J. (2019). Equine de-worming: a consensus on current best practice. *UK-Vet Equine*, 3(1): 1-14. doi.org/10.12968/ukve.2019.3.S.3

Wood, S.J. (2010). *Some factors affecting the digestible energy requirements and dry matter intake of mature donkeys and a comparison with normal husbandry practices* (PhD Thesis). Retrieved from http://hdl.handle.net/1842/4817

Wood, S.J., Smith, D.G., Morris, C.J., & Cuddeford, D. (2012). The effect of pasture restriction on dry matter intake of foraging donkeys in the United Kingdom. In: Saastamoinen M., Fradinho M.J., Santos A.S., Miraglia N. (eds) *Forages and grazing in horse nutrition*, vol 132. Wageningen Academic Publishers, Wageningen. doi.org/10.3920/978-90-8686-755-4_17

Wylie, C.E., Ireland, J.L., Collins, S.N., Verheyen, K.L.P., & Newton, J.R. (2013). Demographics and management practices of horses and ponies in Great Britain: A cross-sectional study. *Research in Veterinary Science*, 95: 410-417. doi.org/10.1016/j.rvsc.2013.05.004

Ingredient Spotlight: Boswellia

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The use of plants for medicinal purposes stretches back since records began, predominantly focusing on human health, but over recent years there has been growing interest in how certain plants can support animal health. One such plant is Boswellia, which is now extremely popular with horse owners and is available on its own and incorporated into formulated products. This popular ingredient triggers extensive debate amongst owners, primarily focusing on the level of boswellic acids. This debate is valid since boswellic acids are the components of the plant that have been shown to have health benefitting properties (Ammon, 2010; Daly *et al.*, 2011; Roy *et al.*, 2019; Al-Harrasi *et al.*, 2021), however it is not the only consideration. Here at Feedmark we openly acknowledge that the research to date has not provided a minimum boswellic acid requirement for humans or animals, or a recommended boswellic acid level, and therefore we should not focus solely on the level of boswellic acids in products. Boswellic acid profile, feeding level and feeding form are important factors that also need to be considered when wanting our horses to benefit from Boswellia.

Figure 1. Boswellia serrata tree that produces resin (insert) within its trunk and branches which is harvested for its anti-inflammatory properties

BOSWELLIA THE BOTANIC

Boswellia is one genus within the *Burseraceae* family of plants. Within the *Boswellia* genus there are 28 species names currently accepted (WFO, 2021), although there are names that are synonymous with accepted names, which can lead to confusion on what species are available or included in products (Table 1). Boswellia species are native to tropical America, Africa and Asia, with specific species grown in specific locations (Daly *et al.*, 2011; Iram *et al.*, 2017).

Table 1. Organisation of key Boswellia species

Family	*Burseraceae*	
Genera	*Boswellia*	
Species of interest	*B. serrata (Frankincense)*	*B. sacra Flueck*
Synonymous names	*B. balsamifera Spreng.* *B. glabra Roxb.* *B. thurifera Roxb. ex Fleming.* *Chloroxylon dupada Buch.-Ham.*	*B. carteri Birdw.* *B. bhaw-dajiana Birdw.* *B. undulatocrenata (Engl.) Engl.*
Origins	India	America Yemen Oman Somalia India

The reference to *Boswellia serrata* that is commonly cited in equine information and product pages relates to a specific Boswellia species found in India, and which can be correctly referred to as Indian Frankincense (Figure 1). However, the terms *Boswellia serrata* and Indian Frankincense are often mistakenly used as a generic term

for all Boswellia species, most likely due to *Boswellia serrata* being the most abundant of Boswellia species and the one that seems to be harvested the most for its resin, and not because it is superior compared to other Boswellia species. *Boswellia sacra*, also known as *Boswellia carteri*, is a lesser known Boswellia species that has been shown to contain high levels of boswellic acids and have the same medicinal properties as the more well-known *Boswellia serrata* (Daly *et al.*, 2011; Mannino *et al.*, 2016).

Plants in the Boswellia genus are generally in the form of trees and shrubs which have canals within their trunk and branch structures. Within these canals is resin, also referred to as oleo-gum resin, or simply gum-resin (Daly *et al.*, 2011). The resin is harvested from the Boswellia trees by either slicing or boring into the bark, then dried and processed for use in products. The species from which the resin originates influences its composition and appearance, which can range from clear to milky in colour and from watery to gum-like in consistency (Daly *et al.*, 2011). Reports on the composition of Boswellia resins vary, with the lipophilic parts (fat-loving compounds that dissolve or combine well with fat) of the resin being the most important as these are rich in terpenoids (Al-Harrasi *et al.*, 2018). Al-Harrasi *et al.* (2018) report that resin from *Boswellia carteri* grown in Oman and in its natural state, contained 55-65% lipophilic compounds, whilst Mannino *et al.* (2016) found total lipophilic compounds averaged 55% in *Boswellia serrata* and 60% in *Boswellia carteri*.

So you may be wondering what terpenoids are and why they are important. They are important because boswellic acids comprise of terpenoids, specifically pentacyclic triterpene molecules, and boswellic acids have been shown to have medicinally important qualities and so can be thought of as the active part of triterpenes within Boswellia resin. However, the lipophilic part of Boswellia resin is not all boswellic acids as it contains other terpenes such as mono-, di- and other triterpenes, not just the pentacyclic forms found in boswellic acids. Therefore, any products reporting just the lipophilic component of Boswellia resin will be overestimating boswellic acid levels.

BOSWELLIC ACIDS

As already highlighted, medicinal properties have been attributed to boswellic acids, however research has shown that certain boswellic acids have greater effect than others (Roy *et al.*, 2019), hence the need to consider the boswellic acid profile. Research has identified multiple types of boswellic acids in Boswellia resins, with up to 12 acids being identified within the resin of *Boswellia serrata* and *Boswellia carteri* species (Al-Harrasi *et al.*, 2018; Roy *et al.*, 2019). Six of these boswellic acids have been identified as the main acids associated with inhibiting the enzymes involved in inflammation, although the different acids vary in their contribution to the total boswellic acid content (Table 2).

Table 2. Contribution of boswellic acids to the total boswellic acid content in resin from Boswellia serrata and Boswellia carteri associated with inhibiting inflammation

Boswellic acid (abbreviation shown in brackets)	Contribution towards boswellic acid content
α-boswellic acid (BA) β-boswellic acid (BA)	10 - 21%
Acetylated α-boswellic acid (ABA) Acetylated β-boswellic acid (ABA)	0.05 - 6%
11-keto-β-boswellic acid (KBA)	2.5 - 7.5%
3-O-acetyl-11-keto-β-boswellic acid (AKBA)	0.1 - 3%

In vitro (laboratory based) research indicates that KBA and AKBA are the most potent and effective boswellic acids at down-regulating inflammatory enzymes, thought to be due to the presence of the 11-keto group (Roy *et al.*, 2019). However, some studies indicate that boswellic acids are relatively poorly absorbed and metabolised by the body. The potential limited absorption of boswellic acids is something that is not acknowledged or discussed, yet it is paramount, as having high levels of boswellic acids in a product means very little if those acids are not absorbed by the animal. *In vitro* studies into the ability of boswellic

acids to cross a simulated intestinal wall are inconclusive, with some studies finding low permeability for AKBA, and moderate permeability for a *Boswellia serrata* extract (Krüger *et al.*, 2009), whilst another *in vitro* study found both KBA and AKBA were very permeable (Gerbeth *et al.*, 2013). The variability in these results shows more research is required to determine the ability of boswellic acids to cross the intestinal wall, and raises the question; *can boswellic acid absorption be increased in any way?*

WHAT ARE TERPENOIDS/TERPENES?

• Terpenoids are constituents of essential oils and are mostly organic compounds consisting of only carbon and hydrogen elements (hydrocarbons).

• The building blocks of terpenoids are 5-carbon isoprene units which have a formula containing 5 carbons and 8 hydrogens, or C5H8 [CH2=C(CH3)-CH+CH2].

• Terpene hydrocarbons have the formula $(C5H8)_n$, with the *n* dictating how many units of isoprene are involved.

• Terpene hydrocarbons are classified according to the number of isoprene units:

Monoterpenes =	2 isoprene units =	10 carbons
Sesquiterpenes =	3 isoprene units =	15 carbons
Diterpenes =	4 isoprene units =	20 carbons
Triterpenes =	**6 isoprene units =**	**30 carbons**
Tetraterpenes =	8 isoprene units =	40 carbons

• Triterpenes are further classified, with pentacyclic triterpenes being one of these groups.

The lipophilic nature of boswellic acids limits their solubility in water but increases their ability to combine with fats, therefore it was hypothesised that feeding the acids alongside fat could increase their absorption. Research in humans indicates that administering boswellic acids orally with a meal containing fat increases absorption of the acids, based on a greater increase in plasma boswellic acid levels after consumption with a fat-based meal compared to consumption of the acids alone (Sterk *et al.*, 2004). Such findings offer potential for increasing boswellic acid absorption in horses as the feeding of fat in the equine diet is relatively common and is easily achieved. Piperine, a compound found in Black Pepper (*Piper nigrum L.*) and Long Pepper (*Piper longum L.*), has been shown to improve boswellic acid absorption in rabbits, and so offers another potential method of increasing boswellic acid utilisation (Vijayarani *et al.*, 2020), although further research is needed to determine the true picture of boswellic acid absorption in horses. Until such research takes place, we should focus on using the most effective sources of boswellic acids and feeding appropriate amounts.

PHYSIOLOGICAL ACTIONS OF BOSWELLIC ACID

Despite the lack of research to demonstrate the beneficial effects of Boswellia in horses, there is a demand for Boswellia equine products, indicating that owners are seeing benefits to feeding this herb. These benefits are mainly due to the anti-inflammatory and immune-supporting actions of Boswellia which have been demonstrated in laboratory studies, human trials (Sengupta *et al.*, 2008) and in dogs (Reichling *et al.*, 2004). General literature states that boswellic acids can modulate enzymes involved in the inflammatory process, namely growth factors, kinases, and transcription factors (Ammon, 2010; Roy *et al.*, 2019). Literature also promotes that boswellic acids can stimulate apoptosis (cell death), which has focused research in humans on the anti-cancer effects of Boswellia. Cancers are relatively rare in equids compared to other conditions therefore Boswellia is not fed for this reason, however the anti-inflammatory properties of Boswellia make it an attractive ingredient for supporting joint function (Figure 2).

Joint issues and mobility support

Osteoarthritis is the most common joint issue affecting humans, horses and dogs (Carmona & Prades, 2009). The condition is characterised by progressive cartilage deterioration, subchondral bone remodelling (changes to the bone under the cartilage), loss of joint space, development of bony projections or spurs (osteophytosis) and pain, leading to reduced function and mobility (Schlueter & Orth, 2004). Regardless of the cause of osteoarthritis, the condition is

associated with inflammation caused by proinflammatory substances which induce degradation of cartilage and the physiological changes described previously.

At the molecular level, osteoarthritis results from an imbalance of substances that promote synthesis of the extracellular matrix (ECM) of articular cartilage, and substances that induce remodelling of these components (Table 3) (Schlueter & Orth, 2004; Carmona & Prades, 2009). To counteract normal degradation (catabolism) of tissue, the body also produces anabolic molecules which function to counteract this degradation and promote growth or repair of tissues. Anabolic molecules are produced to counteract the catabolic effects of joint wear and osteoarthritis however the effects of the catabolic molecules tend to dominate (Schlueter & Orth, 2004; Carmona & Prades, 2009).

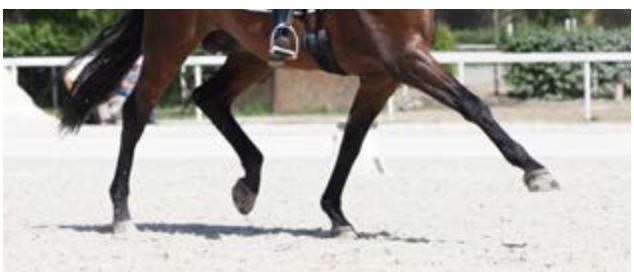

Figure 2. The anti-inflammatory properties of boswellic acids are beneficial for supporting mobility and joint function

Research into the effects of Boswellic acids on inflammation associated with osteoarthritis has shown that they can inhibit and stimulate various molecules. Several of these studies are highlighted below:

- Extracts of specific boswellic acids, AKBA and acetyl α-boswellic acid, inhibited the generation of proinflammatory TNFα *in vitro*, with AKBA being the most active component (Syrovets *et al.*, 2005).
- Boswellia extract containing 30% AKBA (5-Loxin®) prevented TNFα induced expression of MMPs *in vitro* using human cells (Roy *et al.*, 2005). The same extract has also been shown to reduce knee pain and improve function within seven days in humans suffering from osteoarthritis who were administered a daily oral dose of 100mg and 250mg (Sengupta *et al.*, 2008) when used in a double-blind, randomised placebo-controlled trial.
- Boswellia extracts and boswellic acids inhibit the synthesis of leukotrienes which are key pro-inflammatory molecules, with the presence of the 11-keto group thought to be a requirement for this inhibitory action (Roy *et al.*, 2019), explaining the greater effects seen with KBA and AKBA. This inhibitory action is due to boswellic acids inhibiting 5-lipoxygenase (5-LOX), the key enzyme in leukotriene synthesis (Siemoneit *et al.*, 2009). However, these results were gained *in vitro* along with results that indicated that albumin cancels out this inhibitory effect, as albumin binds to 11-keto-boswellic acids. Albumin is a key component of blood therefore boswellic acids may not be effective in reducing leukotriene synthesis due to being bound to albumin once absorbed. Further research is required to confirm such findings.

Table 3. Key molecules involved in osteoarthritis in equids

Key molecules involved in inflammation and osteoarthritis in equids	
Catabolic cytokines	Interleukin -1 (IL-1) IL-1β IL-6 Tumor necrosis factor-α (TNF-α)
Extracellular matrix degrading enzymes	Matrix metalloproteinases (MMPs) Serine proteases Aspartic proteases Cysteine proteases
Eicosanoids	Prostaglandins E2 (PGE2) Leukotrienes
Inflammatory mediator	Nitric oxide
Key anabolic molecules associated with osteoarthritis in equids	
Insulin-like growth factors	IGF-1 IGF-2
Transforming growth factor-β (TGF-β)	

- A study feeding a *Boswellia serrata* extract containing >50% triterpenes (actual boswellic acid levels not disclosed) at a dose of 400mg extract/10kg body weight, to 29 dogs with inflammatory joint and spinal disease, found that clinical signs greatly improved over a 6-week period (Reichling *et al.*, 2004). No pharmacological tests were performed so there was no data on absorption or possible modes of action, however clinical assessment of lameness and movement by a veterinary professional indicated much improvement in the dogs.

Gastric, respiratory and immune support

Boswellic acids have been shown to increase antibody production when administered at low doses (25mg/kg BW) to mice, giving them an immunostimulatory action at low doses (Ammon, 2010). However, when given at higher doses (50-200mg/kg BW) this effect is thought to be reversed, having an immune-depressing action (Ammon, 2010; Roy *et al.*, 2019). Such effects could be deleterious depending on the situation, for example conditions caused by over activity of the immune system could be perpetuated if low doses of boswellic acids are given, whereas feeding a similarly low dose to rundown horses could stimulate immunity with beneficial effects. For these reasons it is important to discuss your horse's requirements, and the potential for Boswellia to support your horse, with your vet if they have immune related issues.

Boswellic acids are also promoted for their gastroprotective and calming properties and are proposed as support for inflammatory bowel disease and diarrhoea (Ammon, 2010; Roy *et al.*, 2019). Studies in rats show that boswellic acids have an antispasmodic action which calms the digestive tract, reduces motility leading to a slowing of digesta passage and reduced diarrhoea (Borrelli *et al.*, 2006). In addition, boswellic acids are thought to protect against gastric ulcers in rats due to their inhibitory effect on 5-LOX, thus inhibiting the synthesis of pro-inflammatory leukotrienes (Ammon, 2010). This link has not been established in horses but certainly warrants further investigation due to the prevalence of gastric ulcers in horses, particularly performance horses.

The inhibitory effect of boswellic acids on leukotrienes is also associated with the respiratory supporting qualities of Boswellia (Ammon, 2010). Leukotrienes are known to induce bronchoconstriction and mucus secretion (Ammon, 2010) which reduce respiratory efficiency and make breathing even harder for those with sensitivities to certain particles such as dust or pollens. Scientific studies to support the use of Boswellia for respiratory health in animals are lacking however the lack of studies indicating any negatives of giving respiratory sensitive animals Boswellia indicates it is safe to feed for such issues.

SUMMARY

Boswellia is a herb with many qualities that are beneficial to our horses, with its anti-inflammatory action offering the most potential for a range of issues. This review has highlighted that the boswellic acid profile, boswellic acid level and mode of feeding should all be considered, with the feeding of fat and Piperine offering potential to increase absorption. The feeding of Boswellia extracts is one option for providing the important boswellic acids, however there is no recommended minimum boswellic acid level. Feeding 20g of a dried boswellia resin which contains 35% boswellic acids provides more boswellic acids than feeding 10g of a boswellia extract containing 65% boswellic acids, and unless stated the boswellic acid profile is unlikely to be known. Use of products that have a high percentage of total boswellic acids and specifically AKBA, the most potent inflammatory inhibiting boswellic acid, will provide excellent support to your horses, although such concentrated boswellic acids are more costly, meaning the decision as to which form of boswellia you feed has another factor to consider.

There is criticism about the lack of supporting research for herbal supplements, however we believe owners know their horses the best and can make informed decisions on what works for their horses. Boswellia resin and Boswellia extracts do have research supporting their actions, although we would always like studies conducted on horses.

REFERENCES
Al-Harrasi, A., Khan, A.L., Rehman, N.U., & Csuk, R. (2021). Biosynthetic diversity in triterpene cyclization within the Boswellia genus. *Phytochemistry*, 184: 112660. doi.org/10.1016/j.phytochem.2021.112660
Al-Harrasi, A., Rehman, N.U., Khan, A.L., Al-Broumi, M., Al-Amri, I., Hussain, J., Hussain, H., & Csuk, R. (2018). Chemical, molecular and structural studies of Boswellia species: β-Boswellic Aldehyde and 3-epi-11β-Dihydroxy BA as precursors in biosynthesis of boswellic acids. *PLoS ONE*, 13(6): e0198666. doi.org/10.1371/journal.pone.0198666
Ammon, H.P.T. (2010). Modulation of the immune system by Boswellia serrata extracts and boswellic acids. *Phytomedicine*, 17: 862-867. doi:10.1016/j.phymed.2010.03.003
Borrelli, F., Capasso, F., Capasso, R., Ascione, V., Aviello, G., Longo, R., & Izzo, A.A. (2006). Effect of Boswellia serrata on intestinal motility in rodents: inhibition of diarrhoea without constipation. *British Journal of Pharmacology*, 148(4): 553-560. doi:10.1038/sj.bjp.0706740
Carmona, J., & Prades, M. (2009). Pathophysiology of Osteoarthritis. *Compendium Equine*, January/February: 28-39.
Daly, D.C., Harley, M.M., Martínez-Habibe, M.-C., & Weeks, A. (2011). Burseraceae. In: Kubitzki, K. (ed) *The Families and Genera of Vascular Plants ,Volume X Flowering Plant Eudicots*. Springer, Berlin, Germany.
Gerbeth, K., Hösch, J., Fricker, G., Werz, O., Schubert-Zsilavecz, M., & Abdel-Tawab, M. (2013). *In vitro* metabolism, permeation, and brain availability of six major boswellic acids from Boswellia serrata gum resins. *Fitoterapia*, 84: 99-106. doi.org/10.1016/j.fitote.2012.10.009
Iram, F., Khan, S.A., & Husain, A. (2017). Phytochemistry and potential therapeutic actions of Boswellic acids: A mini-review. *Asian Pacific Journal of Tropical Biomedicine*, 7(6): 513-523. doi.org/10.1016/j.apjtb.2017.05.001
Krüger, P., Kanzer, J., Hummel, J., Fricker, G., Schubert-Zsilavecz, M., & Abdel-Tawab, M. (2006). Permeation of Boswellia extract in the Caco-2 model and possible interactions of its constituents KBA and AKBA with OATP1B3 and MRP2. *European Journal of Pharmaceutical Sciences*, 36(2-3): 275-284. doi:10.1016/j.ejps.2008.10.005
Mannino, G., Occhipinti, A., & Maffei, M.E. (2016). Quantitative Determination of 3-O-Acetyl-11-Keto--Boswellic Acid (AKBA) and Other Boswellic Acids in *Boswellia sacra* Flueck (syn. B. *carteri* Birdw) and *Boswellia serrata* Roxb. *Molecules*, 21(10): 1329. doi.org/10.3390/molecules21101329
Reichling, J., Schmökel, H., Fitzi, J., Bucher, S., & Saller, R. (2004). Dietary support with Boswellia resin in canine inflammatory joint and spinal disease. *Schweiz Arch Tierheilkd*, 146(2): 71-79. doi: 10.1024/0036-7281.146.2.71
Roy, N,K., Parama, D., Banik, K., Bordoloi, D., Devi, A.K., Thakur, K.K., Padmavathi, G., Shakibaei, M., Fan, L., Sethi, G., Kunnumakkara, A.B. (2019). An Update on Pharmacological Potential of Boswellic Acids against Chronic Diseases. *International Journal of Molecular Science*, 20 (17): 4101. doi.org/10.3390/ijms20174101
Roy, S., Khanna, S., Shah, H., Rink, C., Phillips, C., Preuss, H., Subbaraju, V.G., Trimurtulu, G., Krishnaraju, A.V., Bagchi, M., Bagchi, D., & Sen, C.K. (2005). Human Genome Screen to Identify the Genetic Basis of the Anti-inflammatory Effects of Boswellia in Microvascular Endothelial Cells. *DNA and Cell Biology*, 24(4): 244-255.
Schlueter, A.E., & Orth, M.W. (2004). Equine osteoarthritis: a brief review of the disease and its causes. *Equine and Comparative Exercise Physiology*, 1(4): 221-231. doi:10.1079/ECEP200428
Sengupta, K., Alluri, K.V., Satish, A.R., Mishra, S., Golakoti, T., Sarma, K.V.S., Dey, D., & Raychaudhuri, S.P. (2008). A double blind, randomized, placebo controlled study of the efficacy and safety of 5-Loxin® for treatment of osteoarthritis of the knee. *Arthritis Research & Therapy*, 10(4): R85. doi.org/10.1186/ar2461
Siemoneit, U., Pergola, C., Jazzar, B., Northoff, H., Skarke, C., Jauch, J., & Werz, O. (2009). On the interference of boswellic acids with 5-lipoxygenase: Mechanistic studies *in vitro* and pharmacological relevance. *European Journal of Pharmacology*, 606: 246-254. doi:10.1016/j.ejphar.2009.01.044
Sterk, V., Büchele, B., & Simmet, T. (2004). Effect of food intake on the bioavailability of boswellic acids from a herbal preparation in healthy volunteers. *Planta Med*, 70(12): 1155-1160. doi: 10.1055/s-2004-835844
Syrovets, T., Büchele, B., Krauss, C., Laumonnier, Y., & Simmet, T. (2005). Acetyl-Boswellic Acids Inhibit Lipopolysaccharide-Mediated TNF-α Induction in Monocytes by Direct Interaction with IκB Kinases. *The Journal of Immunology*, 174(1): 498-506. doi.org/10.4049/jimmunol.174.1.498
Vijayarani, K.R., Govindarajulu, M., Ramesh, S., Alturki, M., Majrashi, M., Fujihashi, A., Almaghrabi, M., Kirubakaran, N., Ren, J., Babu, R.J., Smith, F., Moore, T., & Dhanasekaran, M. (2020). Enhanced Bioavailability of Boswellic Acid by *Piper longum*: A Computational and Pharmacokinetic Study. *Frontiers in Pharmacology*, 11: 551911. doi:10.3389/fphar.2020.551911
WFO (2021). World Flora Online: Boswellia. Published on the Internet; http://www.worldfloraonline.org. Accessed 29 March 2021.

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Nutrition of the mare during foaling and lactation

Abigail Malone, BSc

It can be a nerve-racking time when breeding horses, with many management and nutritional factors to consider along the way. Factors generic to all broodmares and their foals need to be considered in the context of the individual animal's requirements to allow appropriate decisions to be made that support the health and welfare needs of the mare and her foal.

The gestation period averages 340 days (11 months) but can vary between 320 and 380 days (Satué *et al.*, 2011). Gestation length, and therefore foaling date is influenced by environmental, foetal, and most importantly maternal factors (Satué *et al.*, 2011). Environmental factors influencing gestation length include seasonal conditions or climate, the amount of sunlight the mare receives each day (also known as photoperiod), and when the mare was mated within the season. Many studies including one by Cilek (2009) found that gestation length was significantly reduced when mares were mated at the end of the season (July to November) compared to at the start (January and February). Foetal factors include genetics, the sex of the foetus, and the type of pregnancy, with research showing that male foetuses tend to lead to slightly longer pregnancies, whilst in the case of twins, if the pregnancy is successful, the gestation period tends to be much shorter (Satué *et al.*, 2011). Maternal factors such as nutritional state, age, breed and number of births the broodmare has had, if any, will effect gestation length. Older mares may have decreased nutritional efficiency of their uterus and placenta, meaning that gestation length is increased as the growth process becomes slower (Wilsher & Allen, 2003), and mares who receive optimal nutrition, rather than just a maintenance diet, have been seen to have shorter gestation lengths (Satué *et al.*, 2011).

What the foal is being bred for is likely to determine the month that it is due. For example, a foal that is expected to have a racing career is likely to be due earlier in the foaling season than a sport or leisure horse, as those with racing careers begin training much sooner and so will be more developed if they are born earlier. Some more commercial broodmares may have a foal every year, making the first month after having the previous foal incredibly crucial to set her up within a short time period for her next pregnancy. Studies have shown that day length can affect foaling dates (Cilek, 2009) with longer gestation lengths decreasing the possibility of mares coming back into oestrus within the same covering season (Dicken *et al.*, 2012). Although many breeders will know the due date of the foal, a vet can help determine this more accurately using blood tests and scans, to ensure you are ready for the birth.

All of these factors must be considered when predicting the date that the mare is due to foal and begin lactating. Feeding requirements are not only different as the pregnancy and lactation period progresses (Lewis, 1995), but are also dependent on the time of year and weather conditions as the nutritional quality of grazing will vary (see *Fuel or filler? What is the real nutrient content of grass for horses?*) and poor weather increases the mare's energy requirements. The mare can start lactating early, up to a month before foaling, or wait until only a few hours before giving birth before she produces any milk (Thomas, 2020). Lactation will continue until the foal is weaned or until approximately 6 months after giving birth. Lactation is a critical period in the mares breeding cycle as it is the most nutritionally demanding period for the mare as she provides nutrients to the growing foal (Lawrence, 2013). Milk yields can range from 2 to 3% of the mare's body weight per day, so for a 500kg mare this equates to her producing 10-15 litres of milk daily. Such demands make it easy to understand why her nutritional needs are at maximum during the lactation

period. Providing a diet that meets the mare's nutrient and energy requirements will allow her to adequately nurse her foal whilst remaining healthy herself.

CONSIDERATIONS DURING FOALING

Whilst foaling may be unexpected, many signs are clear and round the clock observations can ensure help can be provided quickly if any problems occur. Many births occur during the evenings and early morning, although there is always the chance of a daytime birth (Dicken *et al.*, 2012). Monitor the mare's mammary gland for when she begins bagging up (Figure 1), which usually occurs two to three weeks before foaling whilst waxing often appears in the last few days of pregnancy (Thomas, 2020). Behavioural signs such as the mare seeming unsettled, restless, or stressed, and abnormal movements can indicate labour has begun. Defecating and urinating little and often, and not wanting to eat as much as normal are further signs of imminent labour, however these signs are similar to those exhibited by horses with colic, meaning it can be difficult to differentiate between signs of labour and those of colic (Chenier & Whitehead, 2009). Colic is common amongst heavily pregnant and newly birthed mares, therefore close monitoring of the mare is needed (Steel & Gibson, 2002).

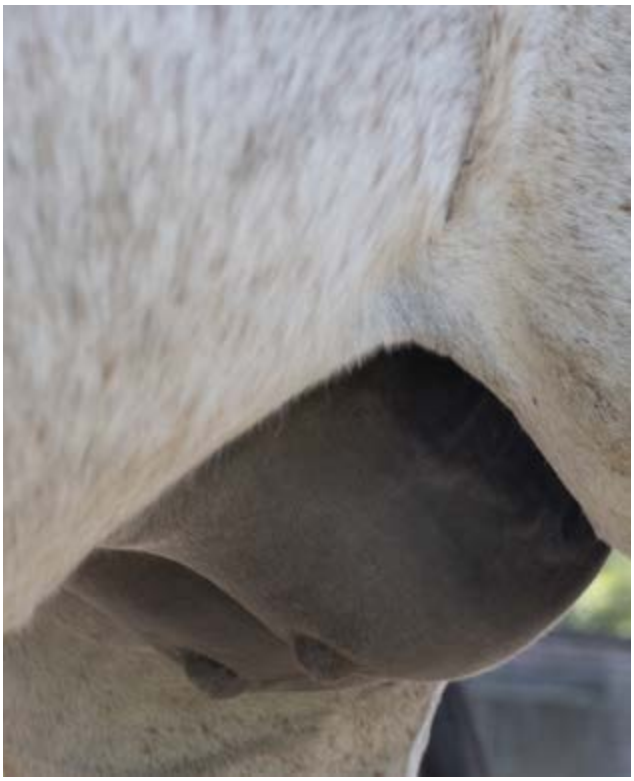

Figure 1. Mare with an enlarged udder, also known as 'bagging up', due to the production of milk in preparation for birth of the foal

Making the mare as comfortable as possible is key, so by keeping the mare in a regular routine and keeping her calm leading up to, during, and immediately after the birth will aid the chances of the mare's survival and a safer delivery of her foal. Maintaining her routine includes what she is fed as sudden dietary changes can increase the risk of colic (Lawrence, 2013). Providing a feed that can be gradually increased in quantity when needed, rather than completely changing the feed type or brand, is preferable. The diet should be palatable to encourage eating and optimise intake and based on an ample supply of suitable forage.

The nutritional needs of the mare change throughout her gestation period as placental growth takes place during early pregnancy and the final three to four months is when the majority of foetal growth takes place. From the fifth month of gestation onwards the mare's energy and crude protein requirements increase, therefore an increase in dry matter intake (DMI) is likely needed (Lawrence, 2013). Kubiak *et al.* (1989) found that providing excess energy in late gestation did increase the mare's body weight and condition but did not increase the foal's birth weight, however horses that have their late gestation period in the winter months may have increased energy requirements due to more energy being needed to maintain body temperature (Lawrence, 2013). Ideally the pregnant mare's diet will contain 16% crude protein (CP), with a good supply of Lysine, the first limiting amino acid making it an essential amino acid. The Lysine requirement can be calculated by multiplying the CP requirement by 4.3%, therefore high-quality protein must be provided in the diet (NRC, 2007). Cereal grains are often low in essential amino acids and therefore provide low-quality forms of protein, whereas high-quality protein can be found in feedstuffs such as Soya bean meal, Brewer's Yeast and Alfalfa.

Vitamin A and E requirements are higher than that for maintenance throughout pregnancy whilst Calcium and

Phosphorus needs increase a small amount in months 7-8 and larger amounts in months 9-11. Copper and Iodine requirements also increase in months 9-11 but there are no increased needs for Iron, Manganese, Zinc or Selenium (Lawrence, 2013). From this information it is easy to see why increasing a general vitamin and mineral supplement could meet the increased requirements of certain nutrients, but oversupply other nutrients. Feed or supplements specifically designed for breeding animals is advised to ensure requirements are met in the correct balance.

The addition of prebiotics and probiotics can be helpful in supporting the normal function of the mare's gastrointestinal tract, although these should be incorporated into her normal diet prior to the physically demanding labour. Turning the mare and the new-born foal out to pasture as soon as possible helps to keep the mare moving and grazing, and may also reduce the risk of colic.

CONSIDERATIONS DURING LACTATION

Pasture is the most desirable source of forage for the lactating mare as it provides a better source of energy, protein, vitamins and minerals compared to preserved forages such as hay (Lawrence, 2013). Despite being such a good food source, pasture may not necessarily provide all nutrients the mare requires as its nutrient content depends on various factors such as the grass species, soil type, climate, and time of year that the mare is grazing. Analysing soil and grass can be helpful but can prove expensive and might not always be accurate. Providing a feed or supplement specifically designed for breeding mares is advised to ensure all nutrient demands are met. Mares that are to be stabled more frequently will also require additional vitamins and minerals through a concentrate feed or supplement. The better the quality of forage the mare receives, the lower the amount of concentrate feed she will need to be fed, however not all vitamin and mineral requirements may be met if feeding less than the recommended daily amount of feed, meaning supplementation is likely to be needed. If mares are kept as a group at pasture, it may be difficult to feed individually and ensure they are receiving the desired nutrients, so feeding in individual stables or pens can ensure the correct amounts are received.

NUTRITIONAL REQUIREMENTS

The lactation period brings about the most sudden changes in nutrient requirements and this is when the broodmare's nutritional needs increase the most. Providing the mare with optimum nutrition will enable her to produce enough high-quality milk for her foal. In the first month of lactation a 500kg mare will produce an estimated 16.3 litres per day of milk (Table 1), with this amount reaching maximum when the foal reaches about 6 weeks of age (NRC, 2007). After this period the amount of milk gradually reduces, coinciding with a slowing of the foal's rate of growth (average daily gain in body weight measured in kg). By the sixth month of lactation the same mare would be producing only 10.9 litres of milk per day (NRC, 2007).

Table 1. Average milk production (litres/day) for a 500kg mare during months 1, 3 and 6 of lactation, and the average growth rate of a foal at months 1, 3, and 6 of age

	Month 1	Month 3	Month 6
Mare's average milk production (litres/day)	16.3	15.0	10.9
Foal's average daily gain (kg/day)	1.1	1.0	0.8

The nutritional needs of the mare vary in response to her maintenance requirements and stage of lactation, with early lactation classed as up to 12 weeks and late lactation being from 12 weeks onwards (Lawrence, 2013). Maintenance requirements are the amount of nutrients the mare requires to maintain her own body and normal functions, which increase by approximately 10% in lactating mares. Mares managed outside will have higher maintenance requirements as they generally spend more time moving and also have to regulate their own temperature in different weather conditions. In addition to maintenance requirements, the mare also requires specific nutrients for milk production, with the higher milk production in early lactation requiring higher nutrient intakes compared to requirements during late lactation when milk production is less (NRC, 2007).

Table 2. Daily nutrient requirements of a 500kg broodmare in the first and sixth month of lactation

NRC requirements	Month 1 of lactation	Month 6 of lactation	% change from month 1 to month 6
Digestible Energy (Mj)	133	114	-14%
Crude Protein (g)	1535	1265	-18%
Amino Acids			
Lysine (g)	85	67	-21%
Macro Minerals			
Calcium (g)	59	37	-37%
Phosphorus (g)	38	23	-39%
Sodium (g)	13	12	-8%
Chloride (g)	46	46	0%
Potassium (g)	48	34	-29%
Magnesium (g)	17	8.7	-49%
Sulphur (g)	15	15	0%
Trace Elements			
Cobalt (mg)	0.5	0.5	0%
Copper (mg)	125	125	0%
Iodine (mg)	3.5	3.5	0%
Iron (mg)	500	500	0%
Manganese (mg)	400	400	0%
Zinc (mg)	400	400	0%
Selenium (mg)	1	1	0%
Vitamins			
Vitamin A (IU)	30000	30000	0%
Vitamin D (IU)	3300	3300	0%
Vitamin E (IU)	1000	1000	0%
B1 - Thiamine (mg)	37.5	37.5	0%
B2 - Riboflavin (mg)	25	25	0%

Calculations based on NRC (2007) recommendations

Table 2 shows the nutrient requirements of a 500kg mare in her first and sixth month of lactation, respectively.

ENERGY

The energy requirements of the lactating mare are almost double that of a mare at maintenance or in the early stages of pregnancy. As energy demand is associated with the amount of work the body has to do to produce milk, the highest energy demands for the mare are during early lactation (Lewis, 1995; NRC, 2007) due to her having to produce large volumes of milk for her rapidly growing foal. Table 2 shows how the energy demand at six months lactation is reduced, although it still remains considerably higher than the energy requirement of even mares at the end of their pregnancy. The mare is able to convert about 60% of her digestible energy into milk energy (Lawrence, 2013) and providing a diet of good quality forage can reduce the need for concentrates to be fed to meet energy requirements (Doreau *et al.*, 1988). Sufficient good quality grazing and hay are likely to be able to meet the broodmare's energy needs, however all horses will greatly vary so must be reviewed individually, with assessment of their fat stores

the easiest way of determining if your mare requires more or less energy, as energy consumed in excess of requirements will be stored as fat. It is possible that feeding a mare on a forage only diet throughout her gestation, whilst meeting her energy requirements, could reduce the risk of her foal developing osteochondrosis by eight times compared to those fed concentrates during gestation (Chavatte-Palmer *et al.*, 2017). It should also be noted that providing the mare with excess energy will not increase the growth rate of the foal and may even produce higher quantities of less concentrated milk (Pagan & Hintz, 1986).

Figure 2. A balanced diet is essential for the mare to ensure her milk can provide the nutrients the foal needs for correct growth and development

If the mare's diet is severely deficient in energy, especially if she has a low body condition score prior to foaling, then she will likely lose weight and this can reduce foal birth weight and growth (Doreau *et al.*, 1988; Chavatte-Palmer *et al.*, 2017). If only in moderate energy deficit (80% of energy requirements met) it is unlikely to have any effect of foetus growth or the foal's growth after birth due the placental adaptation (Chavatte-Palmer *et al.*, 2017).

PROTEIN AND PROTEIN QUALITY

Protein requirements for a mare in early lactation are triple those of the mare when she is not pregnant (NRC, 2007). This considerable increase in protein requirements shows how simply feeding more feed is unlikely to meet nutritional demands of lactation, as the mare would need to consume large amounts of feed to satisfy protein demands which would likely result in too much energy being consumed and an increase in fat stores. The mare's requirements for protein are greatly increased due the vast amount of protein passing from her to the milk. Mares are able to convert approximately 35-40% of their crude protein intake into milk protein, depending on the protein quality, and so a good balance of amino acids and highly digestible protein should be provided (Lawrence, 2013). Insufficient protein in the diet over a prolonged time will decrease milk production and cause the mare to lose muscle and topline, whilst a diet containing protein comprising non-essential amino acids (known as low quality protein) results in a reduced milk yield (Lawrence, 2013).

We can see from Table 2 that in the early stages of lactation, a 500kg mare requires 85g of the essential amino acid Lysine and so over 5% of her crude protein intake must contain Lysine. Due to the requirement for essential amino acids in the body, it is more important to meet the amino acid requirements of the mare than the overall crude protein needs. Achieving this may mean that the amount of protein in the diet is increased to meet the amino acid demand (Lawrence, 2013).

VITAMINS AND MINERALS

Whilst some vitamins and minerals may have a greater influence than others, it is not only the quantities that they are supplied in the diet that must be considered. Some nutrients should be fed in the diet in specific ratios to aid correct utilisation and avoid them competing for absorption or influencing the uptake of other nutrients, especially when some are provided in excess (NRC, 2007).

CALCIUM AND PHOSPHORUS

The Calcium to Phosphorus ratio in the horse's skeleton is 2:1, and 1.7:1 within the whole body (Frape, 2010). Calcium is the mineral that creates a strong skeletal system and therefore the lactating mare has an increased demand to ensure that her suckling foal receives sufficient quantities for its skeleton to growth and develop. Calcium requirements for lactating mares are 1.8 to 2.8 times higher

than a horse at maintenance, with the highest levels during the early stages of lactation (months 1 to 3) (NRC, 2007). Providing insufficient Calcium increases the chances of bone demineralisation, yet over-supplementing does not provide any additional benefit to the foal's skeletal development (Lawrence, 2013). The NRC (2007) also shows that Phosphorus requirements increase by similar amounts (1.7 to 2.7 times maintenance requirements), with the highest levels during early lactation.

OTHER NUTRIENTS

Iodine is highly digestible (Frape, 2010) and is vital for the synthesis of thyroid hormones such as thyroxine and triiodothyronine, which are needed to regulate the horse's basal metabolic rate (energy expenditure at rest) (NRC, 2007). Selenium also aids thyroid hormone metabolism as well as acting as an antioxidant (NRC,2007). The trace nutrients Iodine and Selenium play an important role and should be balanced in the diet as these trace elements can affect the mare's fertility and viability of her foal, whether the mares diet is providing excess or deficient amounts (Frape, 2010).

Vitamin E is a well-known antioxidant crucial to support the horse's immune system and can often be seen paired in supplements with Selenium. Whilst toxicity of Vitamin E is unlikely, inadequate intake of Vitamin E and Selenium during the mare's pregnancy and lactation period has a direct effect, causing deficiency in her foal from birth to one month of age (Lawrence, 2013). A study by Bondo and Jensen (2011) found that supplementing mares with Vitamin E during the late gestation period resulted in higher levels of immunoglobulins in their milk and their foals were found to have improved immunoglobulin levels and Vitamin E status.

The mare will also have an increased need for water with studies showing that broodmares require 1.8 to 2.5 times more water than is needed for a horse at maintenance. Keep clean fresh water available at all times, ensuring troughs do not freeze if outside. Monitoring the mare's water intake just prior and during labour can indicate potential problems.

MONITORING BODY CONDITION AND FAT STORES

Monitoring the fat stores of the mare is a simple yet effective way of adjusting the amount of energy being

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consumed as it allows the breeder to visually monitor the mare with little stress or change in routine. Maintaining optimum fat stores is key throughout the pregnancy and crucial during lactation as some mares prone to weight gain, such as heavy breeds or ponies, will require close monitoring and an appropriate feeding regime to reduce excess fat accumulating. Excess body weight also increases strain on the musculoskeletal system which can impair her mobility and comfort.

If energy requirements are not met, the mare will use her own body fat stores to continue lactating, resulting in weight and condition loss (Lawrence, 2013). A suckling foal can rapidly lower the fat stores of an already thin mare. Once a lactating mare has lost condition it can be difficult to regain as an increased amount of feeding, especially large volumes of concentrates, could lead to other risks such as colic. This emphasises the importance of the mare being in optimal condition before foaling. A mare with excessive weight and a mare that is underweight can both cause issues during foaling and there can be ongoing implications for the mare's health.

SUMMARY

Caring for the broodmare can seem daunting as there are many factors to consider, however it should be remembered that the mare can be fed and managed as normal until the 5th month of pregnancy, when the requirements of energy and some nutrients increase. After this time it is recommended to review her diet and management to optimise foetal development and mare health, and to keep these under review throughout the remaining pregnancy and during lactation, making any changes gradually. For many mares a forage-based diet supplemented with vitamins, minerals and quality protein will meet all of their requirements whilst avoiding the likelihood of excess weight gain.

REFERENCES

Bondo, T., & Jensen, S.K. (2011). Administration of RRR-α-tocopherol to pregnant mares stimulates maternal IgG and IgM production in colostrum and enhances vitamin E and IgM status in foals. *Journal of Animal Physiology and Animal Nutrition*, 95(2): 214-222. doi.org/10.1111/j.1439-0396.2010.01043.x

Chavatte-Palmer, P., Peugnet, P., & Robles, M. (2017). Developmental programming in equine species: relevance for the horse industry. *Animal Frontiers*, 7(3): 48-54. doi.org/10.2527/af.2017-0128

Chenier, T.S., & Whitehead, A.E. (2009). Foaling rates and risk factors for abortion in pregnant mares presented for medical or surgical treatment of colic: 153 cases (1993-2005). *The Canadian Veterinary Journal*, 50(5): 481-485.

Cilek, S. (2009). The survey of reproductive success in Arabian horse breeding from 1976-2007 at Anadolu State farm in Turkey. *Journal of Animal and Veterinary Advances*, 8(2): 389-396.

Dicken, M., Gee, E.K., Rogers, C.W., & Mayhew, I.G. (2012). Gestation length and occurrence of daytime foaling of Standardbred mares on two stud farms in New Zealand. *New Zealand Veterinary Journal*, 60 (1): 42-46. doi:10.1080/00480169.2011.632340

Doreau, M., Martin-Rosset, W., & Boulot, S. (1988). Energy requirements and feeding of mares during lactation: A review. *Livestock Production Science*, 20(1): 53-68. doi.org/10.1016/0301-6226(88)90053-X

Frape, D. (2010). *Equine Nutrition and Feeding*, 4th Ed. Wiley- Blackwell, UK.

Kubiak, J.R., Evans, J.W., Potter, G.D., Harms, P.G., & Jenkins, W.L. (1989). Parturition in the multiparous mare fed to obesity. *Theriogenology*, 32(1): 27-36.
doi:10.1016/0093-691x(89)90518-9

Lawrence, L.M. (2013). Feeding Stallions and Broodmares. In: Geor, R.J., Harris, P.A., & Coenen, M. (eds) *Equine Applied and Clinical Nutrition*. Elsevier Ltd, UK.

Lewis, L.D. (1995). *Equine Clinical Nutrition: Feeding and Care*. Williams & Wilkins, USA.

NRC (2007). *Nutrient Requirements of Horses*, 6th Ed. The National Academies Press, Washington, USA.

Pagan, J.D., & Hintz, H.F. (1986). Composition of milk from pony mares fed various levels of digestible energy. *The Cornell Veterinarian*, 76(2): 139-148.

Satué, K., Felipe, M., Mota, J., & Munoz, A. (2011). Factors influencing gestational length in mares: A review. *Livestock Science*, 136: 287-294. doi.org/10.1016/j.livsci.2010.09.011

Steel, C.M., & Gibson, K.T. (2002). Colic in the pregnant and periparturient mare. *Equine Veterinary Education*, 14(5): 5-15. doi.org/10.1111/j.2042-3292.2002.tb01788.x

Thomas, H.S. (2020). How to Predict Foaling. Published on the Internet; https://thehorse.com/148247/how-to-predict-foaling/. [Accessed 1 April 2021]

Wilsher, S., & Allen, W.R. (2003). The effects of maternal age and parity on placental and fetal development in the mare. *Equine Veterinary Journal*, 35(5): 476-483. doi:10.2746/042516403775600550

Nutrition for hoof health

Abigail Malone, BSc

Multiple factors influence the health and quality of our horse's hooves, and as the old phrase goes "no hoof, no horse". A survey conducted by Thirkell & Hyland (2017) shows that hoof issues are extremely common, with 89% of UK horses experiencing hoof problems in the last 5 years, therefore it is important to focus on hoof health. The external environment of the hoof influences its structures, with excessively dry conditions being associated with brittle hooves that are prone to chipping and cracking, whilst excessively wet conditions are associated with soft soles. A wet environment does not appear to influence the moisture level of the hoof wall but is thought to increase the incidence of white line disease due to the effects on the sole (Hampson *et al.*, 2012; O'Grady & Burns, 2021). Providing access to a dry area where your horse can spend some of its time is helpful in supporting hoof health, alongside regular cleaning and routine trimming by a qualified professional.

Figure 1. Achieving good hoof health is a combination of appropriate nutrition, suitable management, and regular care

Hoof quality and growth is influenced internally by the horse's genetics and the nutrients it consumes. Genetics are difficult to influence, although some issues such as hoof wall separation disease (HWSD) that affects Connemara ponies, can be reduced by testing for the genetic mutation and not breeding affected animals (Logie, 2017). We know that some horses seem to naturally have strong healthy hooves whilst others struggle with poor hoof quality, with some breeds seeming predisposed to inferior hoof horn quality (Josseck *et al.*, 1995). Aside from genetics, the key to growing strong healthy hooves is feeding a balanced diet that provides all the components required by the body to make the hoof structures. However, for horses and ponies that struggle with weak hoof horn or that have slow hoof growth, providing certain nutrients at higher levels can help the body to produce strong hoof structures. The beneficial effect of feeding such nutrients on hoof quality may not be seen for several months, not because they have no effect, but because mature horses' hooves grow relatively slowly at a rate of 8-12mm per month, meaning it can take 9 to 12 months for changes in hoof quality to be seen (Frape, 2010).

INFLUENCE OF NUTRIENTS ON HOOF HEALTH

A balanced diet means your horse consumes all the nutrients its body requires to maintain health and perform any physiological functions required, such as repair of tissues, growth, exercise, or reproduction. A balanced diet ensures all required nutrients are consumed in appropriate quantities to meet demand but not impair the absorption or function of other nutrients, which can lead to nutrient deficiencies (NRC, 2007). Nutrients are classified into six main categories: water, fats, carbohydrates, protein, vitamins, and minerals. To survive the horse needs to consume specific nutrients from each of these categories, plus energy, although energy is not classed as a nutrient as it is gained from the processing of carbohydrates, fats and proteins (McDonald *et al.*, 2011). Vitamins are organic substances which can be found in the horse's forage and concentrates, and minerals are inorganic elements that come from water and soil that are then absorbed by plants and consumed by the horse. Minerals can be categorised into macro minerals and micro minerals (also known as trace elements), based on the amount they are required in the diet (McDonald *et al.*, 2011).

It is the balance and the combination of these nutrients that will improve hoof health and growth, as some nutrients in excess can be detrimental to hoof development. Table 1 shows the nutrient requirements for a 500kg horse at

maintenance consuming 10kg of food per day (as dry matter), equivalent to 2% of its body weight. The stated requirements are the minimum values for a balanced diet to keep the average horse healthy, with nutrients that play a key role in the health and growth of the hoof shown in bold. We will take a look at these nutrients in more detail.

Table 1. Nutrient requirements for a 500kg horse at maintenance fed at 2% body weight

Nutrient	Daily requirement
Digestible energy (Mj)	69.7
Crude protein (g)	630
Amino acids	
Lysine (g)	**27**
Macro minerals	
Calcium (g)	**20**
Phosphorus (g)	**14**
Sodium (g)	10
Chlorine (g)	40
Potassium (g)	25
Magnesium (g)	7.5
Sulphur (g)	15
Cobalt (g)	0.5
Trace elements	
Copper (mg)	**100**
Iodine (mg)	3.5
Iron (mg)	400
Manganese (mg)	400
Zinc (mg)	**400**
Selenium (mg)	**1**
Vitamins	
Vitamin A (IU)	**30,000**
Vitamin D (IU)	3,300
Vitamin E (IU)	**500**
B1 (Thiamine) (mg)	30
B2 (Riboflavin) (mg)	20

Calculations based on NRC (2007) recommendations

ENERGY AND FOOD INTAKE

All horses are recommended to be fed 2% of their body weight daily on a dry matter (DM) basis, with at least 1.5% of their body weight being fed as forage, although higher forage intakes are ideal for general and digestive health. Feeding less forage than this is likely to cause problems such as gastric ulcers and colic, and could be detrimental by way of lack of correct nutrients for hoof health. If horses are in negative energy balance, either purposefully due to being on a diet, or due to an inappropriate food intake, they will first utilise their body fat stores with the potential of then using their protein stores to provide energy, thus reducing the availability of protein to support hoof health, which can have detrimental effects on hoof health as we will later discuss. A study by Butler & Hintz (1977) showed a 50% greater growth in the hoof wall with ponies fed a positive energy balance compared to those on restricted diets. Such findings indicating that equids on a restricted diet may benefit from feeding additional nutrients.

A study using 48 horses by Ley *et al.* (1998) over a 12-month period showed that seasonal movements and nutritional regimes significantly affected the strength of the horses' hoof wall as well as its mineral composition. Horses fed a more balanced diet, according to the NRC recommendations at the time, had greater hoof tensile strength, showing that a forage-only diet is unlikely to provide the horse with sufficient nutrients for a balanced diet, and that horse owners should consider ways to feed nutrients that will optimise hoof growth rate and quality horn production.

In a study by Jancikova *et al.* (2012) horses supplemented with vitamins, minerals and amino acids had 22.3% higher hoof horn growth with sufficient quality, than a control group of horses not being fed the supplement. These findings support an earlier study Butler & Hintz (1977) which reported a 50% increase in hoof horn growth rate when ponies were fed an *ad libitum* pelleted feed compared to those with a restricted ration. Although this type of feeding may not be appropriate for all horses and ponies, it does lead us to believe that those on a restricted diet would benefit from supplementation of certain nutrients.

PROTEIN AND AMINO ACIDS

The hoof comprises mainly of keratin, a protein made of amino acids which contributes to the durable structure of the hoof wall (Frandson & Spurgeon, 1992). As the horse is not able to produce all the amino acids it requires, some amino acids must be supplied in the diet, these are referred to as essential amino acids. Amino acids are the building blocks of protein, with Lysine being the first limiting amino

acid, meaning it is the amino acid that is likely to first become deficient in the horse's diet (McDonald *et al.*, 2011). When Lysine is deficient, the synthesis of proteins within the body is limited, even if all other amino acids are present in adequate amounts. As such, it is essential to provide adequate Lysine in the diet, with some good sources being Soya bean meal, Spirulina and Fenugreek seeds. Providing Lysine alongside amino acids Threonine and Methionine within the diet will aid keratin synthesis and optimise hoof quality.

Methionine is frequently recommended and can be found in many feeds (alfalfa, sugar beet pulp, rice bran) and supplements. Methionine is important because the horse converts it to Cystine, an amino acid which provides keratin with its structure and durability, however Vitamin B6 (Pyridoxine) must also be present in the diet to allow this to happen (Kellon, 1998). Methionine and Cystine are Sulphur-containing amino acids, a macro mineral also required for keratin growth (Jancikova *et al.*, 2012). Care must be taken not to over supplement the horse's diet with Methionine as it is possible that this may reduce the absorption of Copper, Zinc and Iron (Anon, 1998), leading to white line disease and degeneration of the hoof wall.

A diet that is protein deficient can lead to a slower rate of hoof growth as well as cracking and splitting (Lewis, 1995; NRC, 2007). It is unlikely that a UK forage only diet, especially if limited or no grazing is offered, will provide sufficient levels of Lysine and Methionine, which is where a broad-spectrum vitamin and mineral supplement/balancer, or a specifically designed hoof supplement containing amino acids can help to meet the horse's requirements. Such products are often low in calories making them suitable for those prone to gaining weight.

FATTY ACIDS

Omega fatty acids are long chains of carbon and hydrogen atoms that form polyunsaturated fatty acids (PUFAs) that give structure to the cell walls in the body's tissues and aid the absorption of the fat-soluble vitamins A, D, E and K (NRC, 2007). Fatty acids are components of the cement that binds the individual cells of the hoof and also form a permeable barrier that controls hoof moisture level, making them important for hoof quality. As horses cannot produce their own PUFAs, they must be provided within their diet, making them essential nutrients. Fatty acids have numerous benefits to the horse with omega-3 fatty acids having an anti-inflammatory response, whilst omega-6 fatty acids are proinflammatory, making it more ideal to choose a feed or oil with a higher omega-3 to omega-6 ratio. Marine derived omega-3 sources, commonly from fish and algae, contain eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), whilst those obtained from plants, such as linseed, contain alpha-linolenic acids (ALA). Alpha-linolenic acids are the longest of the PUFAs and can be broken down by the horse to EPAs and DHAs, however the horse is not particularly efficient at undertaking this process, making it more beneficial to provide a marine based omega-3 source (Warren, 2015). Traditionally cod liver oil was used to provide such nutrients however producing fish oil is highly unsustainable and brings about a controversial matter, with horses being naturally vegan some owners may be hesitant to feed a fish-based product, whereas algae is an excellent vegan alternative.

VITAMINS

Biotin (also known as Vitamin B7 and Vitamin H) is the most widely researched vitamin with regards to hoof health, yet it also supports growth of the coat, mane and tail due to its role in the formation of keratin. Whilst B vitamins, including Biotin, are by-products produced from fibre fermentation within the horse's hindgut, it may be beneficial to provide additional Biotin in the diet. In one of the first studies regarding Biotin, Buffa *et al.* (1992) using 24 horses, found that supplementing 15mg of Biotin compared to 7.5mg showed better hoof growth rates and hardness. Further studies showed that supplementing 1mg of Biotin per day to a 500kg horse is adequate to support general health (Geyer, 2005), however a study by Josseck *et al.* (1995) showed that feeding 20mg per day to a 500kg horse had a more positive effect on hoof health and growth. Reilly *et al.* (1998) found a 15% increase in hoof horn growth rate after 5 months, after supplementing ponies at a higher rate of 0.12mg/kg body weight, equivalent to 60mg for a 500kg horse. It is advised that horses who are prone to weak, brittle or cracked hooves, receive long term supplementation of Biotin to maintain the growth rate of the horn (Geyer and Schulze, 1994) as when supplementary

dietary Biotin is reduced or removed, the hoof may once again deteriorate. When looking for an additional feed or supplement for hoof health it is advisable to select one with 20mg per day or above for a 500kg horse.

It is important to meet the requirements of all vitamins, not just Biotin, to maintain the general health of the horse, and is one reason it is necessary to provide feeds and supplements that provide balanced nutrients. Many vitamins are sensitive to ultraviolet light, therefore forage will lose a large proportion of its vitamin content during the harvesting process and these levels will continue to deplete over time in storage. Many nutrients within hay are also lost through the soaking process, so if this is a practice you use for your horse's forage, evidence suggests that a vitamin and mineral supplement will support deficiencies and provide known amounts.

Figure 2. A diet deficient in some amino acids, vitamins and minerals can lead to slow hoof growth rate and hoof horn that is prone to cracking

MINERALS

Zinc and Copper

Zinc is a trace mineral that is responsible for numerous roles within the equine body such as growth rates and cell division (Kellon, 1998). Zinc is involved in the uptake of amino acids and Sulphur, and thus the synthesis of keratin. For Zinc to be absorbed it must be provided in the correct ratio to Copper, another trace mineral, at 4 parts Zinc to 1 part Copper (4:1). Zinc can be found in high concentrations within the hoof tissue and so a deficiency can be easy to detect. Slow hoof growth, thin walls and weak horn can all indicate a Zinc deficiency (Kellon, 2019). Copper aids the formation of bone and connective tissues including the cross-links within keratin that give the hoof its strength and density, with deficiencies causing abnormalities in the bone, connective tissues and potentially reducing hoof growth (Kellon, 1998). Increased cases of laminitis, thrush and abscesses could also indicate Zinc and Copper deficiencies (Kellon, 2019). Some farriers have now even started to use Copper nails when shoeing horses due to Coppers potential antibacterial effect, although this depends on the type of shoe used. A study by Jancikova *et al.* (2012) using 16 Warmblood horses showed that providing supplemental Copper and Zinc increased the content of these trace elements found within the dry matter of the hoof horn.

A study by Higami (1999) found that horses were more likely to experience white line disease when consuming a low Copper and Zinc diet compared to those supplemented with raised levels of these trace minerals. UK soils are often low in Copper and Zinc which generally means that the forage grown in these soils are also low in these nutrients. Horses grazing such areas or consuming forage harvested from such land may be more susceptible to associated deficiencies, meaning an additional supply of such nutrients are required through the feed or supplementation.

Calcium and Phosphorus

Calcium is a macro mineral and is required in all horses' diets to support the development of many structures within their body, such as bones, teeth and muscles, as well as for normal hoof growth. Within the actual hoof structure, Calcium is only present in very small quantities, yet it is vital to help make cross-links of Sulphur between proteins in the hoof horn (Geyer, 2005), in turn creating a stronger and healthier hoof. A study by Ley *et al.* (1998) showed that seasonal changes affected the Calcium content of hooves in 48 Thoroughbred horses, with horses showing a significantly higher Calcium content within their hooves during spring, summer and autumn compared to the winter, likely due to higher Calcium content within forage and grass.

We can see from table 1 that Calcium is a large proportion of the minerals required for a balanced diet which can vary significantly depending on the individual horse's needs. Taking these variations into account will ensure that there is no deficiency. Young horses, breeding horses and those in hard work will require increased levels of Calcium and a deficiency may cause a loss of tubular structure within the inner walls of the hoof structure (Frape, 2010). It must not be forgotten that Calcium should be balanced with Phosphorus in the ratio at 2 parts Calcium to

1 part Phosphorus (2:1). If the Phosphorus intake is higher than that of Calcium, then Calcium absorption may be hindered leading to chronic Calcium deficiency, even if the actual level of Calcium in the diet meets requirements (NRC, 2007).

Selenium

Selenium has become popular within equine supplements as it is an antioxidant that prevents the oxidation of fats and aids correct muscle development in the horse (NRC, 2007). We are all aware that providing a balanced diet is important, but it is just as important not to over supplement. As shown in table 1, the recommended maintenance daily feeding rate for the average 500kg horse is 1mg of Selenium. Horse owners must be careful not to over supplement their horse's diets with Selenium as high levels are extremely toxic and Selenium toxicity can have detrimental effects on the hooves, leading to sloughing, cracking, and in severe cases shedding of the hoof wall (Frape, 2010). Geyer (2005) found that excess Selenium caused the decay of the hoof horn close to the coronet band. The levels of Selenium in soils can vary greatly, causing a range of concentrations in grazing and forages, making a further case for the benefits of testing your soil and forage for Selenium levels.

METHYL SULPHONYL METHANE

Typically known for its joint supporting qualities, Methyl sulphonyl methane (MSM) is also high in biologically available Sulphur, which is important for keratin formation. Therefore, supplementation with MSM can help improve hoof quality (Frape, 2010).

SUMMARY

We have explored the nutritional needs for hoof health from general diet to more key nutrients, showing that with regards to correcting abnormalities or weaknesses, nothing is a quick fix. The addition of nutritional supplements present many benefits, which are seen through continued use over an extended period of time, and which allow the renewal and growth of the whole hoof. It is clear that an all-round balanced diet is needed, with close attention paid to the initial forage consumption followed by the provision of additional Biotin, amino acids, omega-3 fatty acids, as well as various minerals. As some horses may have higher nutritional demands depending on factors such as genetics or their environment, it is crucial to analyse each horse or pony's needs on an individual basis to provide them with opportunity for the most improvements.

REFERENCES

Anon (1998). Nutritional needs of the hoof. *Journal of Equine Veterinary Science*, 18(7): 456. doi.org/10.1016/S0737-0806(98)80037-3.

Buffa, E.A., Van Den Berg, S.S., Verstraete, F.J.M., & Swart, N.G.N. (1992). Effect of dietary biotin supplement on equine hoof horn growth rate and hardness. *Equine Veterinary Journal*, 24(6): 472-474. doi.org/10.1111/j.2042-3306.1992.tb02879.x

Butler, K.D., & Hintz, H.F. (1977). Effect of Level of Feed Intake and Gelatin Supplementation on Growth and Quality of Hoofs of Ponies. *Journal of Animal Science*. 44(2): 257-261. doi.org/10.2527/jas1977.442257x

Frandson, R.D., & Spurgeon, T.L. (1992). *Anatomy and Physiology of Farm Animals*,5th Ed. Lippincott Williams & Wilkins, USA.

Frape, D. (2010). *Equine Nutrition and Feeding*, 4th Ed. Wiley- Blackwell, UK.

Geyer, H. (2005). Nutritional Management to keep the Hoof Health. In: A.Lindner (ed.). *Applied Equine Nutrition: Equine Nutrition Conference (ENUCO) 2005*. Netherlands: Wageningen Academic Publishers. 43-58.

Geyer, H., & Schulze, J. (1994). The long-term influence of biotin supplementation on hoof horn quality in horses. *Schweizer Archiv fur Tierheilkunde*, 136(4): 137-149.

Hampson, B.A., Laat, M.A., Mills, P.C., & Pollitt, C.C. (2012). Effect of environmental conditions on degree of hoof wall hydration in horses. *American Journal of Veterinary Research*, 2: 435-438. doi:10.2460/ajvr.73.3.435

Higami, A. (1999). Occurrence of white line disease in performance horses fed low zinc and low copper diets. *Journal of Equine Science*. 10: 1-5. doi.org/10.1294/jes.10.1

Thirkell, J., & Hyland, R. (2017). A Preliminary Review of Equine Hoof Management and the Client–Farrier Relationship in the United Kingdom. *Journal of Equine Veterinary Science*, 59: 88-94. doi:10.1016/j.jevs.2017.10.005

Jancikova, P., Horky, P., & Zeman, L. (2012). The effect of feed additive containing vitamins and trace elements on the elements profile and growth of skin derivatives in horses. *Annals of Animal Science*, 12(3): 381-391. doi:10.2478/v10220-012-0032-4

Josseck, H., Zenker, W., & Geyer, H. (1995). Hoof horn abnormalities in Lipizzaner horses and the effect of dietary biotin on macroscopic aspects of hoof horn quality. *Equine Veterinary Journal*, 27(3): 82-175. doi:10.1111/j.2042-3306.1995.tb03060.x

Kellon, E.M. (1998). *Equine Supplements and Nutraceuticals: A Guide to Peak Health and Performance Through Nutrition*. United States of America, Breakthrough Publications.

Kellon, E.M. (2019). Feeding for Horse Hoof Health by Dr Kellon. Published on the Internet; https://forageplustalk.co.uk/feeding-horse-hoof-health-dr-kellon/. [Accessed 30 March 2021]

Lewis, L.D. (1995). *Equine Clinical Nutrition: Feeding and Care*. United States of America, Williams & Wilkins.

Ley, W.B., Pleasant, R.S., & Dunnington, E.A. (1998). Effects of season and diet on tensile strength and mineral content of the equine hoof wall. *Equine Veterinary Journal*, 26: 46-50.

Logie, S. (2017). Hoof wall separation disease. *Equine Health*, 35: 18-20. doi:10.12968/eqhe.2017.35.18

McDonald, P., Edwards, R.A., Greenhalgh, J.D.F., Morgan, C.A., Sinclair, L.A. & Wilkinson, R.G. (2011). *Animal Nutrition*, 7th Ed. Pearson Education Ltd.

NRC (2007). *Nutrient Requirements of Horses*, 6th Ed. Washington, USA, The National Academies Press

O'Grady, S.E., & Burns, T.D. (2021). White line disease: A review (1998-2018). *Equine Veterinary Education*, 33(2): 102-112. doi.org/10.1111/eve.13201

Reilly, J.D., Cottrell, D.F., Martin, R.J., & Cuddeford, D.J. (1998). Effect of supplementary dietary biotin on hoof growth and hoof growth rate in ponies: a controlled trial. *Equine Veterinary Journal*, 26: 51-57. doi.org/10.1111/j.2042-3306.1998.tb05122.x

Warren, H. (2015). Algae for Horses. *Equine Health*, 21: 10-13. Doi.org/10.12968/eqhe.2015.1.21.10

Research Roundup: Highlights from the 10th European Equine Health & Nutrition Congress

The European Equine Health & Nutrition Congress is an international meeting of equine professionals that takes place every two years. The 10th Congress has the theme 'Fibre First' and is taking place virtually over five separate dates throughout 2021 and 2022. The first two days took place on 25th and 26th March this year, with the first day focusing on forage and the second day focusing on parasite control. After presentations there was plenty of discussion, and with delegates from 39 countries in attendance, views and experiences varied widely.

The need for forage to be the foundation of all equine diets was cemented in the first presentation delivered by Professor Harris (WALTHAM Petcare Science Institute), with the term forage referring to whole plants (except roots) of grass or legume species, in either fresh form as grass or preserved as hay or haylage. This definition supports the points emphasised in the article *Fuel or filler? What is the real nutrient content of grass for horses?* that grass, as well as preserved forages, are important sources of energy and nutrients that need to be accounted for in our horses' diets. Indeed, Professor Harris demonstrated that forage only diets can provide adequate energy for horses performing high levels of exercise but emphasised that the variability in nutrients within forages means the horse's other nutrient requirements are unlikely to be met from forage alone. Forage nutritional analysis is the key to balancing the diet and selecting a suitable feed or supplement, although it was acknowledged that there is variability in analytical methods and standards used by labs meaning owners should select analytical services that use labs with good in-house quality control systems.

The next presentation by Professor Hesta (Ghent University) shared findings from a study into the feeding practices of horse owners in Belgium and Netherlands. This study wanted to find out if the recommendation that forage should form the foundation of all equine diets is being put into practice by owners. Overall, 63% of owners were feeding the minimum recommended amount of forage (1.5% body weight as dry matter) which is an encouraging result, however this still meant that over a third of owners were not feeding adequate forage that we know is needed for gastrointestinal and mental health of our equines. Owners were also asked if they viewed forage as important for their horse's health and all survey participants stated it was important, indicating that there is discrepancy between what people value in theory, and the choices they make when managing their horses. These results are similar to previous studies undertaken in other countries and indicate that more needs to be done to support owners in providing suitable diets.

The final presentation of day one was very useful for providing such support to owners as it reviewed what we know about managing our horses' grass intake. Dr. Longland (Equine and Livestock Nutrition Services) discussed the effects of grazing time, grass height, strip grazing and the use of muzzles on grass intake. Many of the points of this presentation are covered in detail in the article *Managing our horse's grass intake*. The take home messages are that many horses, ponies and donkeys will consume high volumes of grass if permitted which often leads to weight gain, and for some animals can trigger health issues such as laminitis, therefore a suitable method of controlling that intake is likely to be required. A combination of approaches is most likely required as equines have shown great ability to adapt to grazing practices and compensate for periods when grass intake is limited. Finding out what works best for your horse, pony or donkey and with your facilities may take some trial and error, but it is important to be able to manage their grass intake.

Day two of the congress began with Professor Claerebout (Ghent University) providing a comprehensive review of the different parasite species affecting horses, their life cycles, and monitoring techniques available. Key to reducing parasite infections is breaking the parasite's life cycle, which for horses with access to pasture, means reducing the number of parasite eggs and larvae in the grass, so horses cannot be reinfected, and the life cycle cannot continue. The most effective way of achieving this is to monitor horses to identify those who shed eggs and larvae, and therefore need treatment with anthelmintics (wormers), and identify those who are not shedding eggs/larvae and therefore do not requirement treatment. By only treating those that shed, the levels of anthelmintic resistance will be reduced. This is extremely important as no new anthelmintic treatments are being developed. Monitoring is straightforward with faecal egg counts, saliva tests and blood tests. Professor Claerebout explained that the amount of testing performed should reflect the potential risks, so for premises where field groups are relatively stable, testing 3-4 times in the grazing season is likely to be suitable, and composite samples, where faecal samples from multiple horses (maximum 10 samples) are put together and a subsample taken and tested, are an option. On premises where field groups change frequently, more frequent testing of individual animals is recommended. Testing younger horses more regularly is also recommended as they are more susceptible to parasite infections. In some countries testing for parasite infections is not widely practiced, however the high level of uptake in the UK, Denmark and Netherlands was highlighted as a success. In the UK the high level of testing may be due to the availability of advice and testing services from vets and Suitably Qualified Persons (SQP's, a UK specific qualification).

The following two presentations gave overviews of parasite issues and control in North-Western Europe (Dr. D. van Doorn, Utrecht University) and Southern Europe (Professor Meana Mañes, University Complutense of Madrid) to reflect differences in the climate of these two areas (temperate vs Mediterranean). Dr. van Doorn explained that development of small strongyle (*cyathostominae*) eggs into larvae on the pasture requires an environmental temperature of approximately 10°C, and that optimum egg-larvae development is achieved with warmer temperatures (20-25°C), leading to higher levels of larvae on pasture during late spring and summer. However, the cooler temperatures of most North-Western European winters do not necessarily kill eggs as is sometimes believed, instead the eggs remain viable during these colder periods and then as temperatures rise, they develop into larvae. It is actually high temperatures that reduce strongyle egg and larvae development, as explained by Professor Meana Mañes. In hotter climates eggs and larvae are more prevalent on pasture during the autumn and reduce over the summer months due to the hot, dry weather. The hot summers however result in high numbers of bot flies, which were the most prevalent parasite reported in the study during this season. These differences highlight how climate should be considered when developing parasite control plans.

For more information about the 10th European Equine Health & Nutrition congress and how you can register for the remaining dates go to www.equine-congress.com/tenth-eehnc

The final sessions of the congress discussed nutritional options for controlling parasite infections. This is a relatively new and exciting area of equine research that has potential to help support other parasite monitoring and treatment practices. Dr. Paz-Silva (University of Santiago de Compostela) explained the concept of biological control which is defined as the use of living organisms to control pests, and how certain fungi have the potential to reduce some parasite infections in equids through their effect on eggs and larvae. Spraying the fungi onto pasture or faecal piles is one method of administration, or another option is to coat feed or treats with fungi, so they are administered direct to the horse where they pass through the gastrointestinal tract undigested and then act within the faeces to disrupt the parasite life cycle. This is a new

concept being applied to equine parasite control however results for small strongyles egg shedding by horses, ponies and zebra show reduced faecal egg counts so there is potential to integrate such methods with other parasite control practices. Dr. Pellikaan (Wageningen University) explained another possible approach to reducing parasite infections in horses, which has been taken from research in ruminants. Tannins are complex compounds found in some plant species. Tannins were previously thought to have harmful effects when consumed by animals, but research has now shown that some tannins have anti-inflammatory, antioxidant, and antimicrobial properties. Dr Pellikaan explained that some tannins are able to bind to parasite larvae within the gastrointestinal tract, preventing the parasite life cycle from continuing. Legume plants such as Sainfoin are potential sources of such tannins, or feeding a supplement or feed containing tannin extracts is another potential option. Although these new methods of controlling parasite infections are still in the experimental stages, it is excellent to see research into this important area. As the research continues and more knowledge and evidence is gained it is hoped such practices will integrate with the monitoring and management practices already utilised, with the overall aim of reducing parasite resistance to anthelmintics, and consequently parasite infections in our horses.

Glossary

Amino acids	Organic molecules that combine to form proteins, also known as the building blocks of proteins.
Anthelmintics	Drugs that expel parasitic worms from the body by either stunning or killing them, and without causing damage to the host animal.
Bagging up	The mare's udder swells due to the production of milk in anticipation of the foals birth.
Basal metabolic rate	The rate at which the body uses energy while at rest to maintain vital functions such as breathing and keeping warm.
Crude protein	Calculated by the nitrogen content of foodstuffs.
Demineralisation	Loss of minerals such as Calcium, from tissues, e.g. Calcium leaves the bones and enters the circulation to maintain blood levels of Calcium if fed a Calcium deficient diet.
Digestibility	Amount of nutrient absorbed by the animal and available for it to use.
Digestible energy	Amount of energy in the feed minus the amount of energy lost in the faeces.
Dry matter	The part of a foodstuff that remains after all water has been removed. Foods are compared on a dry matter basis as nutrients are only contained in the dry matter.
In vitro	Biological processes that occur outside of the body, but within laboratory equipment such as a test tube or culture dish.
In vivo	Biological processes that occur inside a whole living organism, e.g. an animal or person.
Lipophilic	Molecules that are attracted to fats. Such substances are able to dissolve much easier in lipids (fats) than they are in water.
Macro minerals	Minerals required in the diet at levels of more than 100mg/kg diet. Includes Calcium, Phosphorus, Magnesium, Sulphur, Sodium, Chloride and Potassium.
Microbiome	Microorganisms (and their genes) living in a specific environment.
Microbiota	Specific microorganisms (bacteria, protozoa, fungi) living in a specific environment, e.g. the equine gastrointestinal tract.
Microorganism	A microscopic organism, especially bacteria, protozoa and fungi. These live in the equine gastrointestinal tract, with higher populations in the large intestine making up the microbiome.
Oestrus	A recurring period where the female is sexual receptivity, commonly known as being in heat or season.
Substrate	Surface or material on or from which an organism lives, grows, or obtains its nourishment, e.g. undigested food that reaches the equine large intestine and is used by the microorganisms to survive.
Trace elements	Minerals required in very small amounts. Required in the diet at a level of less than 100mg/kg diet. Includes Iodine, Manganese, Zinc, Copper, Selenium and Iron.
Vitamins	Organic compounds which are required in small amounts for normal growth and maintenance of life.

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