Nutritional management of equine gastric ulcers

Over the last 10 years there has been increasing awareness and subsequently recorded cases of equine gastric ulcer syndrome and with this comes an increased interest in appropriate nutrition and feed management. This review presents a systematic approach to assessing the ration of a horse at risk or diagnosed with equine gastric ulcer syndrome and demonstrates the ample evidence upon which to base nutritional recommendations for horses with equine squamous gastric disease, and to a lesser extent, equine glandular gastric disease, with an emphasis on forage. Careful selection and management of the forage ration should be the first step in designing a suitable ration, followed by selection of an appropriately low starch and sugar (less than 2g per kg body weight per day and 1g per kg body weight per meal) complementary feed. There is still more to learn about the role of supplements in the prevention and treatment of equine gastric ulcer syndrome, thus these should currently be viewed as an adjunct to an appropriate base diet and not as an isolated solution.

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For over 30 years, equine gastric ulcer syndrome has been recognised as a common issue afflicting the horse (Hewetson and Tallon, 2021), describing ulcerative diseases of the stomach (Andrews et al, 1999). It has become clear that the pathophysiology differs depending on the anatomical region affected, and the terminology has been refined to describe more specific conditions including equine squamous gastric disease, pertaining to ulcers primarily affecting the non-glandular 'unprotected' (top) region of the stomach, and equine glandular gastric disease which describes ulcers primarily affecting the glandular region (bottom) of the stomach (Sykes and Jokisalo, 2014; 2015a; 2015b; Sykes et al, 2015; Banse and Andrews, 2019; Hewetson and Tallon, 2021).

While both forms of equine gastric ulcer syndrome can be influenced by diet and feed management, the mechanisms behind this seem to vary. This differentiation, along with ongoing advancements in our understanding of the syndrome, improves nutritional management, identification of risk factors and the ability to consider variations of these across the two conditions. The categorisation of ulcers may not only serve to enable superior management and treatment, but may also be instrumental in prevention strategies. This review collates the key advances of the past 10 years, culminating in nutrition and feeding recommendations.

Prevalence

Equine gastric ulcers are reported in all ages and breeds of horse. The incidence of equine squamous gastric disease in researched cohorts is reported to be between 11–92% (Murray et al, 1989; Chameroy et al, 2006; Luthersson et al, 2009; Niedźwiedź et al, 2013) and more than 50% for equine glandular gastric disease (Husted et al, 2010; Hepburn, 2014) (*Table 1*).

Aetiology

Risk factors may differ for equine squamous gastric disease and equine glandular gastric disease. Understanding of the pathophysiology of equine glandular gastric disease remains somewhat limited, but factors contributing to a weakening in mucosal defences (such as stress, inflammation and bacterial proliferation) have been proposed (Sykes et al, 2015; Banse and Andrews, 2019). The aetiology of equine squamous gastric disease is thought to result from an increase in gastric acid exposure (Andrews et al, 2017). While the former is thought to be less directly influenced by nutrition, its management should still be considered as part of an holistic approach (Pedersen et al, 2018; Banse et al, 2018).

Nutrition and associated feeding risks

Equine squamous gastric disease

In cases of primary equine squamous gastric disease (horses with otherwise normal gastrointestinal tracts), key risk factors include fasting, inadequate dietary forage, excess starch intake and exercise (Banse et al, 2018; Hewetson and Tallon, 2021).

Fasting

An interval of more than 6 hours between forage feeds (and thereby a reduction in production of saliva) (Meyer et al, 1985; Argenzio, 1999), has been suggested to increase the risk of equine squa-

Table 1. Prevalence of equine squamous gastric disease and equine glandular gastric disease across various horse specifications

Horse Specification	Prevalence of equine squamous gastric disease	Prevalence of equine glandular gastric disease	Reference
Warmblood Show Jumpers	25%	51%	Pedersen et al (2018)
Thoroughbred racehorses	86%	47%	Begg and O'Sullivan (2003)
Polo horses	37%	31%	Banse et al (2018)
Leisure horses	50%	55%	Hepburn (2014)
Sports horses	50%	62%	Hepburn (2014)
Endurance	67%	27%	Nieto et al (2004)

mous gastric disease by resulting in a lower pH (more acid) in the stomach, increasing the risk of damage to the unprotected part of the stomach (Husted et al, 2009). The pH of the upper stomach has been found to decrease to ≤2 when feed was withheld for 24 hours (Murray and Schusser, 1993). The risk here can relate to both total quantity of dietary forage, its management and the interaction with other risk factors. For example, low forage intake below the recommended minimum value (1.5% body weight in dry matter), resulting in decreased saliva production, combined with high (>2g per kg meal) starch and sugar intake, which increases volatile fatty acid production and reduces mucosal lining integrity, was found to be the most common risk factor associated with equine squamous gastric disease in a cohort of Belgian horses (Videla and Andrews, 2009; Galinelli et al, 2019).

Type of forage

The type of forage used may also increase the risk of equine squamous gastric disease. Luthersson et al (2009) suggested an increased risk of ulcer formation when straw was fed as the sole forage source. This was thought to be a result of the characteristics of straw, most notably its high lignin content and its physical irritation of the mucosal lining. This consideration could be relevant to other forage sources with similar characteristics (Hewetson and Tallon, 2021). However, research by Jansson et al (2021) and Dosi et al (2020) contends this suggestion, with both studies reporting no evidence of gastric ulcers after 21-days and 4 months respectively, in horses fed 50% of their forage ration as straw.

Starch intake

High starch intake has been reported to be associated with an increased risk of gastric ulcers (Metayer et al, 2004). The mechanism behind this is thought to stem from high concentrations of starch and sugar reducing the integrity of the mucosa (Galinelli et al, 2019). Luthersson et al (2009) reported that a starch intake exceeding 2g per kg of body weight per day, or feeding >1g per kg of body weight per meal, was associated with a doubled risk. To put this into context, for a 500kg horse, 2g of starch per kg body weight per day would equate to a kg of starch. A racehorse receiving a typical ration of 7kg dry matter of a racing mix at 32% starch would be receiving a total of 2.24kg of starch from this complementary feed.

Pasture access

Reduced pasture turnout has been associated with an increased incidence of ulcers in the squamous region (Luthersson et al, 2009), although various studies suggest a decreased prevalence of gastric ulcers in grazing horses (Murray and Eichorn, 1996; Hammond et al, 1986; Luthersson et al, 2009). Lester et al (2007) suggested that racehorses with access to at least some turnout were less likely to have ulceration, the risk being reduced further when turned out with other horses. The reasons behind this may include lower stress as part of less intensive management, with increased access to pasture allowing more time foraging and opportunity for social contact, resulting in longer periods of low gastric acidity. This alone should not be seen as 'protective', as several studies report a high prevalence of gastric ulceration in horses with pasture access, although it is worth noting that in many of these studies horses were concurrently fed high starch complementary feeds (Bell et al, 2007; Le Jeune et al, 2009).

Luthersson et al (2009) reported that horses without access to water in their paddock were more likely to have ulcers. It is proffered that sufficient water intake helps to dilute gastric fluid by reducing acidity, so ensuring ad libitum access to water at all times is recommended.

Exercise

Exercise intensity is also considered to influence the risk of equine squamous gastric disease ulcers in horses (Vatistas et al, 1999; Sykes et al, 2019). During exercise, the contraction of the stomach may allow acid from the glandular region to reflux up into the squamous region, resulting in acid injury – commonly referred to as the 'acid splashing' theory (Lorenzo-Figueras and Merritt, 2002). Exercise in trot and above has been shown to dramatically decrease the pH in the squamous region of the stomach. Horses in light to heavy training for as little as 8 days were shown to be at increased risk of developing gastric ulcers (White et al, 2007), with the prevalence of gastric ulcers in racehorses increasing nearly twofold for every week of training (Lester et al, 2007).

Equine glandular gastric disease

Key risk factors identified for equine glandular gastric disease include stress, particle size and frequency of exercise (Andrew et al, 1999; Fedtke et al, 2015; Sykes et al, 2019; Banse and Andrews, 2019). However, from a nutritional standpoint, it is maintained that limiting starch intake and increasing pasture access may be helpful for preventative management (Pedersen et al, 2018; Banse et al, 2018).

Type of forage

The feeding of alfalfa as a forage source has been considered as a point of interest, owing to its high content of 'buffering components' (protein and calcium). Nadeau et al (2000) reported a lower

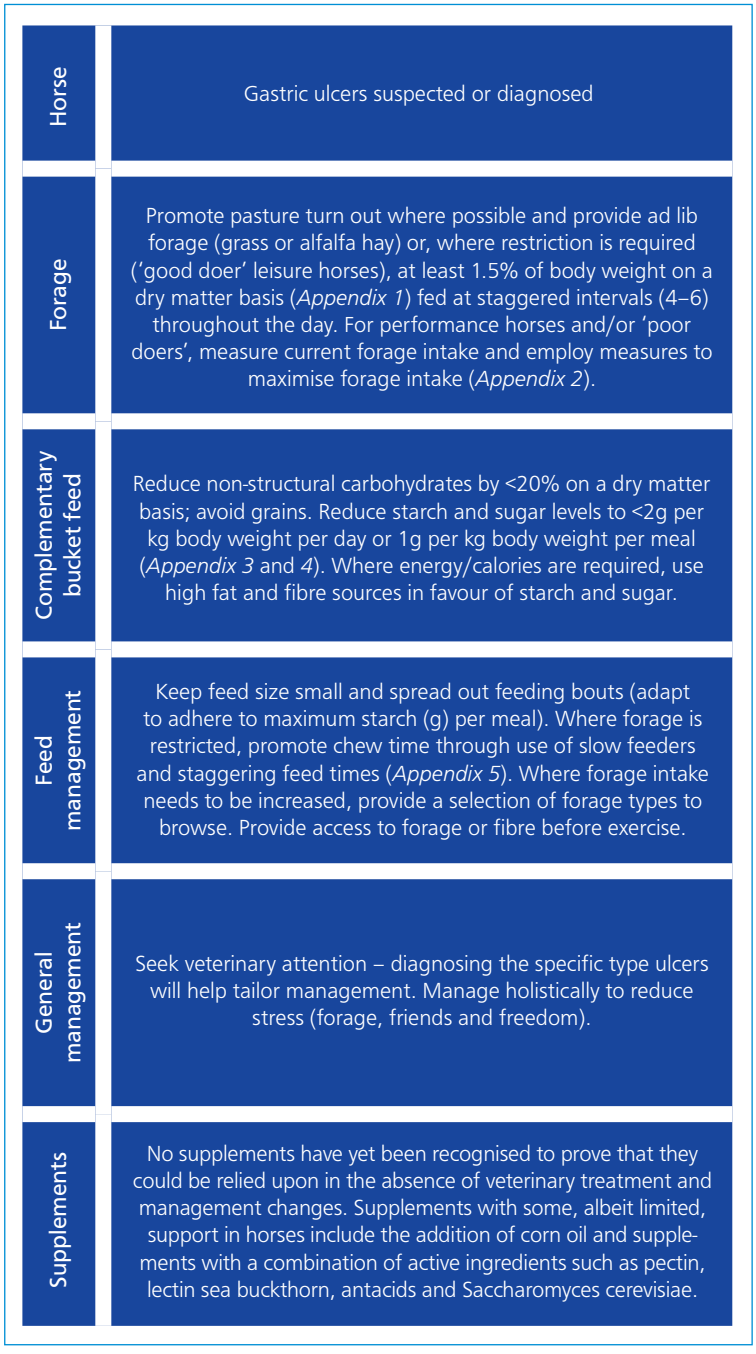

Figure 1. Nutritional management of equine gastric ulcers, adapted from Reese and Andrews (2009); Sykes et al (2015a); Andrews et al (2017); Camacho-Luna et al (2018); Hesta and Costa (2021).

incidence of gastric ulceration in horses where alfalfa hay was the principal forage source. Further studies in weanlings (where ulcer prevalence is known to be high) investigated the potential of feeding alfalfa to moderate ulceration (Fedtke et al, 2015; Vondran et al, 2016), both of which indicated a possible link between particle size and the potential for the physical characteristics of a 'chaff' format of alfalfa to inflict mechanical injury to the mucosa and worsen lesion severity (Fedtke et al, 2015; Vondran et al, 2016). It should be noted that the provision of chaff (and not long fibre) as the sole forage source (as was the case in these studies), is not a commonplace feeding practice and the provision of chaff in smaller quantities has not yet been identified to present the same concern. Vondran et al (2016) compared the feeding of an alfalfa chaff with pelleted alfalfa; the latter was shown to provide the nutritional benefits of the ingredient without increasing gastric lesion severity. This study can be seen as supportive of the initial suggestion from Fedtke et al (2015) that particle size may be an important factor in the occurrence of some gastric ulcer lesions. This finding was further supported by Vondran et al (2017) in a study of adult horses, whereby the feeding of alfalfa chaff was seen to induce glandular mucosal lesions. However, Bäuerlein et al (2020) compared feeding alfalfa hay and meadow hay to healthy adult horses and concluded that there was no significant difference between the feeding groups. From current findings, the physical nature of alfalfa chaff and alfalfa hay and the subsequent particle size appear to be significant. While more research is required, how critical particle size and feed format is may depend upon the individual horse's mucosal integrity, ulcer type and severity.

Designing an appropriate ration

The approach to nutrition and feeding should be informed by the horse itself, its history and ideally a specific diagnosis. The more information available, the more accurately the diet can be tailored. The proposed ration should also consider facilities and the ability of the carer to promote compliance. The aim should be to achieve a high fibre (ad libitum or 1.5% of body weight on a dry matter basis) (Sykes et al, 2015; Andrews et al, 2017) and low starch ration (<20% non-structural carbohydrates) (Camacho-Luna et al, 2018; van Erck-westergren et al, 2019). Reducing the risk of gastric ulcers requires a holistic approach, considering not only medical intervention (if required) but also feed management changes (Luthersson et al, 2019). See *Figure 1* and the associated appendices as a starting point for informed feed and management choices (note that ideally forage should be considered as the first step).

Forage

Where body weight and condition are appropriate, free-choice forage (pasture, hay or haylage) is a desirable foundation of the ration. Where ad libitum forage is likely to result in weight gain, the focus should be on extending 'chew time'. Options to achieve this will ultimately depend on the owner or carer and the facilities available. While fibre restriction is often synonymous with a higher risk of fasting and therefore gastric ulcers, Bruynsteen et al (2015) reported no evidence of ulcers after 16.5 weeks of moderate or severe dietary restriction (80% and 60% of the individual's maintenance energy intake to maintain obese body weight respectively). However, it should be noted that the ponies were group housed outside feeding times which could be responsible for reducing stress levels and associated risk, highlighting the importance of an holistic approach. Soaking hay or sourcing a more mature lower calorie forage is recommended as a first step to increase the volume of hay in the ration. The sugar content of hay can be reduced through soaking for 1–12 hours (Martinson et al, 2012; Longland et al, 2014; Müller et al, 2016); efficacy dependant on the original specification of the forage. The practice is variable in outcome, therefore a selection of suitable forage at the outset or verification of nutrient con-

Table 2. Example nutrient specification of a traditional conditioning mix, a high fibre and oil conditioning feed and a performance balancer

	A	B	C
Product	Traditional conditioning mix	High fat and fibre-based conditioning blend	Performance balancer
Recommended feeding rate	0.6–1.2kg per 100kg body weight	0.6–1.2kg per 100kg body weight	100g per 100kg body weight
Digestible energy (mj/kg)	12.5	13	11
Protein %	12.5	13	26
Fibre %	8	18	7.5
Oil %	5	10.5	7
Starch %	32	8	6
Sugar %	5.5	6	6.5
Total starch and sugar (g) combined when fed at the recommended rate for a 500kg horse in moderate work	1125–2250	420–840	62.5
Starch (g) per kg body weight per day	2.25–4.5	0.84–1.68	0.125
Starch (g) per kg body weight per meal when fed in three meals	0.75–1.5	0.28–0.56	0.04

tent via analysis is recommended wherever possible. Shorter soak times can be coupled with warmer water temperatures to maximise losses (Longland et al, 2014; Rendle et al, 2018). To account for dry matter losses during soaking, pre-soaked hay rations should be increased by 20% (Rendle et al, 2018).

To further increase the time over which forage occupies the horse, feeding times can be spread out throughout the day (Hesta and Costa, 2021) and/or 'slow forage feeders' employed (the latter with reduced reliance on owner or carer labour) (Hallam et al, 2012; Aristizabal et al, 2013; Glunk et al, 2014; Ellis et al, 2015a, 2015b; Morgan et al, 2016; Rochais et al, 2018). There is some evidence to suggest that overnight fasting has minimal effect on stomach pH (horses resting overnight, initiating periods of fasting even where forage is available), in comparison to daytime fasting which instigates significant decreases (Husted et al, 2009). Where possible, this should be considered in the division and measures employed to extend eating time.

For those on restricted rations, do not forget to account for dry matter (using values derived from forage analysis) and if soaking hay for long periods, add a further 20% to account for the losses in dry matter (Rendle et al, 2018).

Providing a minimum of 1.5% body weight in dry matter of long stem forage is recommended for all horses (Harris et al, 2017).

When looking to maximise calorie intake, for example in the case of poorer doers, such as an equine that tends to be underweight and requires significant nutritional input to maintain an appropriate body condition, or for those in harder work, the provision of ad libitum forage and consideration of quality is key. Employing forage analysis and securing a higher quality, more digestible (often less mature 'softer') forage will reduce the reliance on complementary feed for calories, thereby helping to reduce overall starch intake while simultaneously promoting intake and chew time. Forage replacer products can also be considered but are likely to be a less practical and economic solution.

Note that a horse fed ad libitum forage should not be presumed to be consuming adequate dietary fibre. Ascertaining the actual quantity consumed per day by weighing forage 'in' and 'out' can be a valuable exercise. If intake is discovered to be sub-optimal, feeding multiple forage types (hay, haylage, beet and chaff) rather than a single forage source may help to increase intake by mimicking a more varied diet (Thorne et al, 2005).

Complementary feed

Once the forage ration has been assessed, the complementary feed can be considered. Basing the ration on the forage portion and having a more flexible approach can significantly reduce the quantity of complementary feed required. For example, if the calorie/energy requirement can be satisfied from forage alone (which is realistic for many leisure horses), then the complementary feed is only needed to provide micronutrients to balance the forage. As complementary feed is typically the key source of starch in the ration, this approach can help to significantly reduce intake.

With a nutritional profile high in starch (Julliand et al, 2006) and low in calcium and protein, cereals have poor acid buffering capacity and are therefore not recommended for horses prone to ulcers. However, there are some ingredients with properties thought to be beneficial for digestive health. Fibre sources, such as unmolassed sugar beet (also a source of pectins) and alfalfa, may help to improve equine squamous gastric disease scores by promoting chewing and therefore saliva production (in addition to being low in starch and sugar and high in calcium) (Nadeau et al, 2000; Andrews et al, 2006; Lybbert et al, 2007; Andrews et al, 2017). Although, further research is required to investigate the impact of such ingredients on the integrity of gastric mucosa. The pilot study by Cehak et al (2019) reporting negative effects of butyric acid warrants further investigation.

In the case of the 'good doer' (leisure or performance), a balancer (concentrated source of vitamins, minerals and quality protein)

Table 3. Equine-specific research behind common supplement ingredients targeted at horses with or at risk of gastric ulcers

Supplement ingredient (common sources)	Key findings	Research in horses
Antacids (aluminium hydroxide, magnesium hydroxide, magnesium oxide, calcium carbonate)	These have a short-lived effect on horses. While they may be used preventatively, there is not sufficient evidence for their exclusive use in ulcer treatment (Zavoshti and Andrews, 2017)	Yes, but predominantly in combination with other ingredients (Woodward et al, 2014; Jacobs et al, 2020)
Beta glucans (soluble fibre, non-starch polysaccharide) found in the cell walls of cereals and yeast)	Beta glucans and pectins (along with others including Sea Buckthorn berries, liquorice and gum Arabic), are indicated to have acid buffering properties and regulate passage rate, but more research is required to determine to what extent they are beneficial, and to highlight optimum feeding rates (Huff et al, 2012; Luca et al, 2017; Murray and Grady, 2002; Woodward et al, 2014; Lo Feudo et al, 2021)	Minimal research in horses
Pectin (soluble fibre, non-starch polysaccharide, found in the cell walls of fruits and sugar beet)		Yes, but mainly in combination with other ingredients (most commonly pectin-lecithin complex) (Woodward et al, 2014; Sykes et al, 2014)
Corn oil	The addition of 10% corn oil saw reduced glycaemic response and significantly decreased gastric emptying times (Geor et al, 2001). However, the latter is in contrast with findings from Lorenzo-Figueras et al (2005). Cargile et al (2004) reported significantly lower gastric acid output in ponies fed 45ml of corn oil per day (0.1ml per kg body weight). In contrast, Frank et al (2005) reported no improvement in squamous ulcer scores in horses fed 240ml of corn, refined and crude rice bran oil	Yes, but further research with focus on equine glandular gastric disease is required

or fortified low-calorie chaff are appropriate choices. Those with higher calorie/energy requirements should look at feeds based on fibre and oil rather than cereals. It should be noted that at present, there is insufficient research to support the addition of oil to all horses with equine gastric ulcer syndrome 'as standard'. Instead, this should be reserved for the provision of calories in place of starch where required (Martinez et al, 2016). There are many low starch and sugar performance and conditioning complementary feeds available, and the nutrient specifications in terms of overall energy/calories are comparable to those of a more traditional cereal-based feed (*Table 2*).

Starch from the complementary feed should not exceed 2g per kg body weight per day (1000g for a 500kg horse) or 1g per kg body weight per meal (500g for a 500kg horse) (Luthersson et al, 2009). *Table 2* illustrates that when fed at the recommended feeding rate, it is common for more traditional (cereal-based) conditioning and performance feeds to exceed these guidelines.

Always consider the feeding rate when assessing suitability based on nutrient specification. For example, *Table 2* shows three products; at first glance, product B and C look similar in terms of their combined starch and sugar quantity when stated as a percentage. However, once you have considered the feeding rate required to provide a balanced ration, product C would provide much lower levels of starch and sugar as it is a more concentrated product designed to be fed by the 'mugful'.

The British Equestrian Trade Association (BETA) introduced the BETA Gastric Ulcer Feed Assurance Mark in 2016 to help recognise feeds suitable for horses prone to gastric ulcers (BETA, 2022). These products undergo extensive review and are certified based on whether the starch and sugar content are appropriate (based on Luthersson et al, 2009) for horses prone to gastric ulcers when fed at recommended amounts. While not all feeds fitting these criteria will have this mark, it is a good starting point when looking for appropriate feeds.

Supplements

No supplements have yet proven that they could be relied upon solely in the absence of veterinary treatment or management changes. Many ingredients are available both as part of a compound feed and as stand-alone products which are aimed towards horses with, or at risk of, ulcers. There is limited research at present to support the beneficial properties of supplements containing a combination of ingredients for the management of equine squamous gastric disease (Andrews et al, 2017; Conover et al, 2015). *Table 3* provides a summary of these, along with key sources and equine-specific research.

At present, supplements aimed at horses with gastric ulcers may be used to reduce risk of equine gastric ulcer syndrome, in addition to veterinary treatments, but further research with larger sample populations are required. Furthermore, while many of these ingredients may be beneficial for gastric ulcer prevention, the base diet and management should be addressed first (Vervuert and Stratton-Phelps, 2021). Equine-specific research behind common supplement ingredients targeted at horses with, or at risk of gastric ulcers is summarised in *Table 3*.

Feed management

Selecting appropriate feed is just one piece of the puzzle when it comes to managing horses with gastric ulcers. Forage management to promote intake, chew time and spread consumption throughout the day is essential. This should include close monitoring of both forage and water intake during travel, competitions and periods of

stress. For those in exercise, administering a fibre feed (Sykes and Jokisalo, 2015b; Hewetson and Tallon, 2021) within 2 hours before exercise may help form a protective 'fibre mat' in the stomach (Argenzio, 1999), acting as a physical barrier between gastric acid and the squamous region. However, there is a lack of research or guidance on specific recommendations.

Meal size should be primarily governed by starch and sugar content (as previously mentioned) to reduce total intake per day and per meal. However, as a general guide, small, frequent meals (less than 0.5kg per 100kg body weight) of complementary feeds are recommended (Andrews et al, 2006; Bass et al, 2018). Fresh clean water should be available at all times.

General management to promote a 'natural' less-intensive lifestyle where possible to reduce stress (for example, through turnout or social interaction) is recommended (Malmkvist et al, 2012; Scheidegger et al, 2017; Gehlen et al, 2019).

Conclusions

The realities of domestication and the gastrointestinal physiology of the horse mean that all horses (not just the stereotypical 'ulcer horse', typically characterised as a poor doer that is under more intensive management and workload) are predisposed to ulcers (Ward et al, 2015). Clinical signs of ulcers range widely between individual horses, therefore changes in behaviour, however nuanced, should not be overlooked (Chameroy et al, 2006).

Research has emphasised the importance of nutritional management when it comes to treatment of equine squamous gastric disease (Luthersson et al, 2019). When approaching feeding and nutrition to reduce the risk of ulcers, a holistic view is required. Superficial appraisal of the ration, such as the assumption that provision of ad libitum forage meets fibre requirements or judging the appropriateness of complementary feed without considering feeding rate, are commonplace. Reducing overall ulcer risk should stem from everyday management, including reducing exposure to stress (prolonged exposure to which may weaken mucosal defences) and the fundamentals of the diet – sufficient fibre, with low starch and sugar intakes. In the case of both equine squamous gastric disease and equine glandular gastric disease, supplements should be viewed as they are intended – the 'accompaniment' not the foundation.

While veterinary intervention in the treatment of equine gastric ulcer syndrome is part of the treatment strategy, long-term treatment and prevention strategies should involve significant dietary and management changes (Luthersson et al, 2019), the impact of which must not be dismissed. EQ

Conflicts of interest

The author declares that there are no conflicts of interest.

KEY POINTS

- Gastric ulcers are prevalent across a wide range of horses and should not be considered only in the context of the performance horse. This factor can often make feeding recommendations more challenging, particularly for those with ulcers that also require calorie restriction.
- Recent refining of the sub-categories of equine gastric ulcer syndrome has equipped us with the knowledge required to tailor diets more specifically based on an individual's diagnosis.
- When designing a ration, emphasis should be place on the foundation of the ration (selection of appropriate forage), followed by a low starch and sugar complementary feed (a balancer for low calorie/energy requirements or high oil and fibre concentrate feed where additional calories are needed).
- While supplements are available, these should be considered as an adjunct to an appropriate base diet and not a solution in isolation.
- A holistic view should always be taken in the management of gastric ulcers. Recent research emphasises the importance of dietary and management changes for long term treatment and prevention.

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Appendix 1. Calculating theoretical minimum fibre intake

All horses require a minimum of 1.5% of their body weight of fibre (this can include hay, haylage and grass) in dry matter per day. Note that restriction of fibre intake is more typical in leisure horse diets (for calorie restriction) and for performance (such as in racehorses).

Multiply the horse's body weight (kg) by 0.015 to get 1.5% of their body weight. For example, 500kg x 0.015 = 7.5kg dry matter. Once you have the minimum forage quantity in dry matter, divide this by 0.9 for hay and 0.6 for haylage (average dry matter values – note that haylage varies widely from as low as 50% dry matter). This will give you the absolute minimum amount needed per day when this forage is the horse's sole fibre source. Remember that this is the minimum quantity required – those that require more calories/energy can be fed forage on an ad libitum basis (where the forage quality is confirmed, through analysis, as suitable).

Forage nutrient value can vary significantly and visual appraisal alone is insufficient where this forms the basis of a clinical ration. Wet chemistry analysis for sugars is considered the 'gold standard' (being the basis of calibration for near-infrared spectroscopy) (Harris et al, 2018).

Appendix 2. Estimating current forage intake

Record how much hay or haylage and grazing (plus any other significant fibre sources) is currently fed. As minimum forage requirement is calculated in dry matter, convert all these values to dry matter so that they are comparable (multiply 'as fed' quantity of hay by 0.9 and haylage by 0.6) and add together for a total.

Where possible, record actual intake instead of the quantity provided to avoid incorrect assumptions. Note that estimating grass intake is inherently challenging, but a crude estimate can be made using the following equation (assuming the horse is consuming 2% of its body weight):

Quantity of grass in kg dry matter = (number of hours grazing per day ÷ 24) x (2 ÷ 100) x body weight per kg. Note that grass intake various significantly between individuals and the above equation should only be used as a rough guide.

Appendix 3. Calculating theoretical maximum combined starch and sugar intake from complementary feed

Current recommendations suggest that the combined amount of starch and sugar from complementary feed per day should not exceed 2g per kg body weight or 1g per kg body weight per meal. For example, for a 500kg horse the maximum per day would be 1000g (2 x 500); the maximum amount per meal would be 500g (1 x 500). Note that feeds holding the British Equine Trade Assocation (2022) Gastric Ulcer Mark have already been through a screening process which confirms that when fed at the recommended rates, the combined starch and sugar intake does not exceed the daily and per meal values estimated by research to increase ulcer risk.

Appendix 4. Calculating current starch and sugar intake from complementary feed

When trying to interpret what is low enough, make sure you are considering the quantities the product is intended to be fed at, not just the percentage of starch or sugar on the packaging or product literature. To work out the amount of combined starch and sugar in a complementary feed first find the percentage of starch and sugar, then multiply this by 10 (changing the percentage into grams), then multiply by the total number in kg (dry weight) fed per day. For example, if a horse were being fed 3.5kg of a conditioning cube that was 26% starch and 5% sugar the calculation would look at follows:

- 26% of 3.5kg = 0.91kg starch
- 5% of 3.5kg = 0.175kg sugar
  - = 1.085kg starch and sugar combined
- Maximum meal size can then be calculated based on the maximum guideline of 2g per kg body weight per day and 1g per kg body weight per meal.

Appendix 5. Estimating how long forage may be occupying the horse

Where possible get the horse owner/carer to time how long it takes the horse to eat a set amount of their forage ration (1 or 2kg). As a reference point, 40 minutes to consume 1kg of hay is typical (Harris and Arkell, 2005). Repeat this over a few days and this should provide an estimate (albeit crude) of how much time a set amount of forage may last. As horses tend to eat in bouts, basing feed management from just one or two observations may be misleading. This practice can have a significant impact from a compliance point of view as a tangible practical illustration for owners/carers. Using this information, you can discuss whether a slow feeder, or some management to extend eating time may be beneficial. Several studies have reported that use of haynets extends eating time, notably haynets with smaller holes (<75mm) or 'double' or 'triple' layered haynets (Glunk et al, 2014; Ellis et al, 2015a, 2015b; Morgan et al, 2016). While haynets with increasingly smaller holes have not been proven to significantly increase eating time, findings indicate that feeding bouts are spread slightly more across the feeding period when smaller holed nets are used (Glunk et al, 2014; Ellis et al, 2015b; Morgan et al, 2016). Studies have also demonstrated increased consumption time when forage is provided in hay bags and floor based slow feeders (Hallam et al, 2012; Aristizabal et al, 2013; Rochais et al, 2018), although these these are not numerous and further research is required.