Advances in the understanding of laminitis and the role of nutrition in its management

Laminitis heavily impacts the equine population and, for this reason, has long been researched with respect to its prevention, causation, and management. Recent research has uncovered the importance of owner recognition in both the prevention and management of laminitis and highlighted this as a potential area for education. Furthermore, clearer definitions of the syndrome and its causation, along with risk of recurrence, should enable a more tailored approach to nutrition and feed management. Dissemination of current research into feeding practice should be seen as a key part of the 'next steps' in laminitis management and prevention. This review collates current recommendations with applications to practical feeding situations, and demonstrates that while there is information on what constitutes an appropriate diet 'on paper', the practicalities of providing this (particularly where forage is concerned), often represents a barrier to long-term use. It is in this area that future research should focus, to fully realise and benefit from the progress made to date.

https://doi.org/10.12968/ukve.2022.6.1.32

Briony Witherow BSc MSc RNutr, Department of Equine Science, Writtle University College, Essex, UK; Practical Equine Nutrition, Cambridge, UK. briony@practicalequinenutrition.co.uk

Key words: equine | laminitis | obesity | weight loss | grazing | welfare

Laminitis is well documented for its impact on the health, welfare and morbidity of horses. It is a common reason for euthanasia (Barker, 2012; Welsh et al, 2016; Pollard et al, 2019a) and a significant factor in cases of multimorbidity (Welsh et al, 2016). Recent research has significantly progressed our understanding of laminitis and, along with effective dissemination to horse owners and caregivers, continues to provide recommendations for its prevention. This review collates the key advances over the past 10 years and provides recommendations for nutrition and feeding.

Categorisation

Laminitis was previously broadly classified according to the differing pathways presumed to trigger its onset. At present, three main clinical forms of laminitis have been defined (Patterson-Kane et al, 2018; Van Eps and Burns, 2019):

- Endocrinopathic, which is associated with insulin dysregulation following equine metabolic syndrome (EMS), pituitary pars intermedia dysfunction (PPID) or corticosteroid administration (Asplin et al, 2007; de Laat et al, 2012; Meier et al, 2018b)
- Sepsis-related, where systemic inflammation is present (van Eps and Pollitt, 2006; Leise et al, 2012)
- Supporting limb laminitis (Gardner et al, 2017).

While these forms share some mechanisms, there are thought to be unique elements in the pathophysiology (physical processes associated) with each form. These are hyperinsulinemia (excess levels of circulating insulin), for endocrinopathic laminitis; inflammation, for sepsis-related laminitis; and ischemia, for supporting limb laminitis. Endocrinopathic is thought to be the most prolific pathway leading to laminitis, with hyperinsulinemia as one of the unique mechanisms (Karikoski et al, 2011, 2016; de Laat et al, 2019b). The acknowledgement of these unique mechanisms may aid in strategies for prevention and treatment.

Diagnosis

Several studies have raised the potential issue of delayed or absent diagnosis, and the subsequent implications for welfare (Menzies-Gow et al, 2013; Pollard et al, 2018; de Laat et al, 2019a). While Pollard et al (2018) reported that only half of laminitic episodes were confirmed by a vet, de Laat et al (2019a) reported that in over 50% of cases, there was a delay of more than 10 days before seeking veterinary intervention. It is well documented that once clinical signs are evident, damage within the foot is already underway. The best results are obtained from treatment when it is initiated within the first few hours of clinical signs appearing (Menzies-Gow et al, 2013). This could imply the presence of fundamental issues in owner-recognition of laminitis, lack of appreciation of laminitis as a 'veterinary emergency' and a lack of clarity on what is considered 'normal' treatment with regard to the order and timeline of attention from veterinarians and other paraprofessionals.

While recent research has shown owner-reported laminitis to be supported in most cases, by veterinary diagnosis, the same study reported that owners were unable to recognise laminitis in around half of the veterinary-diagnosed cases (Pollard et al, 2018). When investigating why this might be, the study reported that an inability to recognise laminitis was more common where clinical history was unknown and where the owner had no direct previous experience with the disease (Pollard et al, 2018). A delay in veterinary intervention has also been attributed to seeking alternative paraprofessional support, such as farriers (de Laat et al, 2019b).

Clinical signs

The Creating Awareness and Reporting Evidence group has recently published findings from a 4-year project investigating the development of laminitis, as well as owners' ability to recognise laminitis and factors that contribute to its occurrence. It is the most recent publication regarding modifiable factors associated with onset of disease (Pollard et al, 2019b).

Previous publications from the research group have reported that laminitis can occur at different times throughout the year; and while cases of laminitis were reported in all limbs, it is most commonly reported in both of the forelimbs (Pollard et al, 2018). In addition, the most prevalent owner-reported signs were difficulty turning and a short, stilted or lame walk. These findings are in line with previous studies on veterinarian-reported cases (Wylie et al, 2013).

When it comes to identifying laminitis, Pollard et al (2018) reported that some of the 'classic' signs were absent in almost half of the sample population. Only 51% of owners reported a bounding digital pulse (but in 11% of episodes, this was not assessed at all), in contrast to previous studies that reported this to be one of the most common clinical signs (Wylie et al, 2013; de Laat et al, 2019a). However, clinical signs in owner versus veterinary-reported data may vary, potentially indicating a lack of owner knowledge or ability to identify a digital pulse. In the same study by Pollard et al (2018), only 51% of owners reported a reluctance to walk and 51% a shifting of weight from foot to foot. While these two clinical signs are identified in previous literature (and are common in horse-owner targeted texts) the absence of these 'classic' signs may cause confusion and, in some cases, perhaps result in delayed intervention. Results from the Pollard et al (2018) study emphasise the importance of knowing what is normal for your horse, as this can encourage earlier intervention. While the study reports certain clinical signs to be more widely reported than others, no single owner-reported clinical sign was present in every laminitis episode, cementing the importance of owner education on the range of clinical signs.

Risk factors

Wylie et al (2013) reported that a recent (within the previous 3 months) increase in body weight (by owner-assessment) increased the risk of laminitis 4-fold. This suggests that not only weight gain, but the period over which it occurs, is a prominent risk factor. Pollard et al (2019b) also reported weight gain to be associated with higher risk of laminitis. While both studies used owner-reported data, which could be considered a limitation, this accentuates the importance of objective, accessible weight monitoring methods.

Height and breed have previously been cited independently as risk factors (Wylie et al, 2013; Welsh et al, 2017). However, Luthersson et al (2017) and Pollard et al (2019b) suggest a combination of height and breed is more likely to be predictor of laminitis. Interestingly, horse breeds were more prevalent in cases of laminitis that went unrecognised by their owners in comparison to pony breeds (and their respective crossbreeds) (Pollard et al, 2018). Pollard et al (2018) proposes that an over-reliance on breed type for diagnosis or recognition may inadvertently result in owners not considering laminitis as a possibility, ultimately delaying diagnosis and treatment. This emphasises that one isolated risk factor cannot be heavily relied upon for the identification of laminitis.

An area raised in recent research and flagged for further investigation is grassland and forage management. In support of the findings from Wylie et al (2013), a veterinary-led study into laminitis risk factors by Luthersson et al (2017) cited a recent change in grass (within the last 14 days) and consuming what was considered 'high-quality grass' as significant risk factors. Additionally, while Pollard et al (2019b) did not find an association with new or abrupt changes in grass access, they did report an increased risk in horses spending short periods of time on grass in the morning, spending less time stabled, using grazing muzzles for only part of the time while grazing, and those fed ryegrass hay or haylage. As horses in this study were being managed for laminitis, it should be considered that the risk factors identified may not be directly causal. The same study also identified a potential protective factor related to animals whose turnout bordered woodland, lending value to future research on the use of silvopasture practice (management system facilitating woodland grazing) for horses (Orefice et al, 2016).

Endocrinopathic laminitis has been identified as the most common clinical form of laminitis (Karikoski et al, 2011; Patterson-Kane et al, 2018; de Laat et al, 2019a; Durham et al, 2019; van Eps and Burns, 2019), with estimates of endocrinopathies in up to 90% of laminitis cases in horses and ponies presenting with lameness (Donaldson et al, 2004; Karokoski et al, 2011). While Pollard et al (2019b) suggested a strong association between EMS and the rate of laminitis, this was not the case when a previous history of laminitis was adjusted for. This suggests (particularly for owner-reported data) a previous history of laminitis may be a better predictor, in alignment with research on recurrence rates for endocrinopathic laminitis.

Several recent studies also suggest that concurrent PPID and EMS resulted in higher basal insulin concentrations than in horses or ponies with a single underlying factor, and that these are subsequently likely to have increased laminitis risk (Meier et al, 2018a; de Laat et al, 2019a). Animals with higher insulin concentrations are also thought to suffer from more severe laminitis (de Laat et al, 2019a).

The incidence of ecurrence, and thereby potential for history of laminitis, has been reported in two studies at 54.4% and 34.1% (de Laat et al, 2019a, 2019b respectively). Previous studies report recurrence ranging from 30–70% (Menzies-Gow et al, 2013; Potter et al, 2017; Welsh et al, 2017). In another study, around a third of horses diagnosed with laminitis had at least one further occurrence over a six-year period, with a quarter of these having a repeat episode in the same year as the initial diagnosis (Luthersson et al,

2017). de Laat et al (2019b) suggested that endocrinopathic laminitis was likely to recur within two years of diagnosis in a third of cases. These statistics emphasise the importance of being aware of an individual's clinical history, as well as the need for continued management after initial episodes of laminitis. Highlighting the importance of a detailed history, Pollard et al (2019b) reported an association between longer recovery time (judged by the owner) and a higher incidence of laminitis in the future. There is also some suggestion that risk factors for subsequent episodes of laminitis may differ from the first, indicating another area for further research (Welsh et al, 2017).

While research to date has reported seasonal peaks (Menzies-Gow et al, 2010; Wylie et al, 2013; de Laat et al, 2019a), other studies have acknowledged the year-round occurrence of laminitis (Pollard et al, 2019b; de Laat et al, 2019b). Dissemination of this fact to horse owners is key to promoting year-round vigilance and continuation of appropriate precautionary management.

Prevention and practical implications

Addressing knowledge gaps in awareness and recognition of laminitis, along with management of weight and body condition, is important. Looking forward, emerging research into grazing restriction methods (Cameron et al, 2021; Furtado et al, 2021), metabolic profiling for potential risk (Delarocque et al, 2021), and improved understanding of genetics (Galantino-Homer and Brooks, 2020) and the gut microbiota (Langner et al, 2020) are all likely to be pivotal factors in the prevention of laminitis.

Nutrition and feeding

The approach to nutrition and feeding should be informed by the horse itself and its history. The more information available, the more accurately the diet can be tailored (*Figure 1*). The proposed ration should also consider the facilities available and the abilities of the carer, in order to promote compliance. The diet should aim for a non-structural carbohydrate content overall of less than 10% (Geor, 2010). See supplementary *Case Study 1* and *2* for examples.

Complementary feed

In the case of the 'good-doer' (an equine that thrives on minimal calore input and that tends to be overweight), a balancer (concentrated source of vitamins, minerals and quality protein), or fortified low-calorie chaff would be an appropriate choice. Feed selection should be informed by what is required in the context of the whole ration – whether it is simply required to balance the ration,

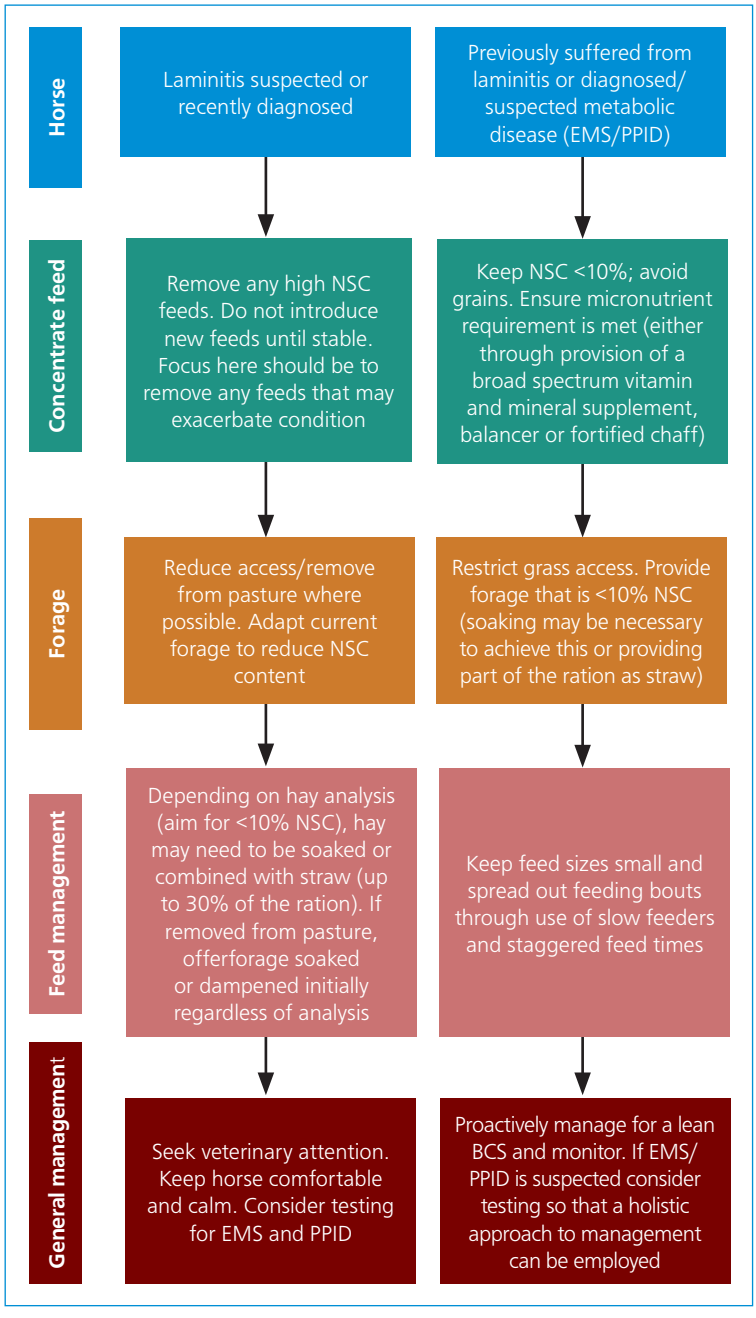

Figure 1. Nutritional management of laminitis (EMS= Equine metabolic syndrome; PPID= Pituitary pars intermedia dysfunction; NSC= Non-structural carbohydrate; BCS= Body condition score.

Table 1. Examples of suitable concentrate feed options for laminitic horses or ponies requiring a low calorie, starch and sugar ration.

Option	A	B	C
Feed(s)	A low-calorie balancer	A low-calorie fortified chaff	A low-calorie balancer with unmolassed sugar-beet
Weight (Volume)	500g (2 mugs)	2.5kg (5 Stubbs scoops)	500g (2 mugs); 125g dry weight (1 Stubbs scoop soaked)
Total non-structural carbohydrate	58g	100g	64g
Total calories digestible energy	5MJ	21.3MJ	6.4MJ

Table 2. Example nutrient specification of a low-calorie balancer and fortified chaff

	A	B
Product	Low-calorie balancer	Low-calorie fortified chaff
Recommended feeding rate	100g/100kg BW	500g/100kg BW
Digestible energy MJ/Kg	10	8.5
Protein %	16	9
Fibre %	12	27
Starch %	6	1.5
Sugar %	5.5	2.5

to extend chew time or as part of a strategy to ease compliance. For example, any of the following options in *Table 1* would offer a balanced ration for a 500kg horse alongside 8.5kg of low non-structural carbohydrate hay but option B or C would provide more volume than option A. This may suit an owner who has been advised to change from a larger concentrate ration, or a horse that is on a very restricted ration (perhaps with limited or no turnout), needing maximum volume and minimal calories. Option A may be more suited to an owner that has not previously has not fed any, or fed very little, hard feed or in a situation where the horse is suitably occupied by the forage ration.

In addition to a balanced complementary feed, salt should also be fed (30g of table salt per day is sufficient to meet the maintenance requirements of a 500kg horse), alongside vitamin E for those without access to fresh forage (National Research Council, 2007).

Considerations

If soaking hay for long periods, elevating feeding rates beyond the baseline recommendations by feeding, for example, the recommendations for moderate work, as opposed to light work, may be necessary to counteract mineral losses from soaking (Moore-Colyer, 1996). This is essential when soaked hay forms part of the long-term feeding strategy.

Always consider the feeding rate when assessing suitability based on nutrient specification. As examples, *Table 2* shows two products. At first glance, product B looks lower in calories, starch, and sugar than product A, but once the feeding rate required to provide a balanced ration has been considered, product A would provide fewer calories and lower levels of starch and sugar (*Table 1*) as it is a more concentrated product designed to be fed by the 'mugful'.

For the poorer doer (an equine that tends to be underweight and requires a good deal of nutritional input in order to keep looking well), look to source calories from fibre and oil sources. It should be noted that many conditioning cubes or mixes would be considered inappropriate with regard to non-structural carbohydrate content. Alternatively, unmolassed beet and alfalfa products

Case study 1. Newly diagnosed laminitis

Profile: 11.2 hands high pony (300kg, body condition score 7/9) newly diagnosed with laminitis (cause and severity yet to be determined but under investigation). Turned out on average grazing in the day and stabled overnight on hay. In light work, no history of laminitis. Fed 0.75kg of a high fibre mix (digestible energy 10MJ/kg; starch 29%; sugar 5%).

Ration comments: The main source of sugar in the ration will be from the hay and grass and the main source of starch from the high fibre mix. The following recommendations look to address this immediately. The following ration assumes a period of box rest, with no grazing, will be implemented.

Recommendations

Concentrate feed:

While the current concentrate feed is a 'high fibre' product, the combined starch and sugar content of 34% is in excess of the recommended <10%. While quantity fed will fundamentally impact how much starch and sugar in grams per day is contributed from this source (in this case 255g), longer-term, a product lower in non-structural carbohydrates would be the preferred solution.

In the immediate term, the recommendation would be to remove this feed from the ration. Short term removal of concentrate feed is not necessarily a cause for concern in terms of an imbalanced ration. However, the introduction of a new complementary feed needs to be done gradually and may be delayed a week or so to allow the owner time to achieve this.

Forage:

The pony should be removed from pasture with immediate effect. While the cause in undetermined, this would represent a significant source of water soluble carbohydrates and calories, and is an element of the ration that is challenging to quantify or control. In the short term, where box rest may be recommended, removal from grass can be helpful in gaining more control over the ration. Much like the concentrate feed, if it is possible to work within the confines of feeds already in the ration, this can be beneficial.

In this case, where the hay is of unknown nutritional value, it would be recommended to soak the hay prior to feeding.

The quantity of hay, where the pony is overweight, should amount to 1.5% of the bodyweight in dry matter (plus 20% when soaking) – 6kg (based on 90% dry matter) per 24 hours.

Longer term considerations:

Once the potential cause and severity of laminitis is determined, a balancer or low-calorie fortified chaff could be introduced gradually. Note that the manufacturers recommended amount for size and workload should be fed as a minimum to help ensure a balanced diet. Where soaked hay is fed as the sole forage source longer term, feeding rates may need to be elevated to counteract leached minerals.

Case study 2. Diagnosed with equine metabolic syndrome

Profile: 16.2hh Warmblood horse (650kg, body condition score 6/9) diagnosed with equine metabolic syndrome 2 months ago (negative for pituitary pars intermedia dysfunction, no history of laminitis). Horse has been removed from pasture since diagnosis and fed 15kg (as fed) of hay, soaked for 6 hours and a few handfuls of unmolassed chaff, in an effort to reduce body weight and condition. The horse is in light work.

Ration comments: The ration is likely to be insufficient in vitamins, minerals and quality protein. While owner-managed weight loss (from obese to lean) should be anticipated to take at least 9 months (progress depending on the owner, horse, and facilities available), if no or very little reduction has been seen to date, further dietary changes should be sought.

Recommendations

Concentrate feed:

The concentrate feed is not sufficient to balance the ration. Feeding either a balancer or the recommended amount of a fortified low calorie, starch and sugar chaff would be suitable options. In either event, dividing the ration over multiple feeds during the day and employing methods to slow intake would be recommended, as even low starch and sugar feeds can initiate exaggerated postprandial responses in insulin dysregulated horses. The ration should aim for <10% non-structural carbohydrate, just as it would for a horse with a history of laminitis.

Forage:

As it represents most of the diet, if the source is consistent, analysis of the hay would be easily justified. This would help to more easily tailor the quantity and management (soaking) of the hay to ensure success of the intervention. The quantity of the hay should be revised, ensuring that a minimum of 1.5% of the body weight is fed. This should be increased by a further 20% to account for dry matter losses from soaking.

For example:

- Calculate 1.5% of current body weight to give quantity of hay required in dry matter (0.015*650=9.75kg dry matter)
- Calculate 20% of the dry matter quantity (0.2* 9.75=1.95kg)
- Calculate total hay required in dry matter by adding 1.5% of body weight in dry matter, plus the 20% projected to be lost through soaking. (9.75 +1.95 = 11.7kg)
- Calculate total hay required as fed (assuming 90% dry matter) (11.7/0.9 = 13kg)

If this would likely result in weight gain, selection of an alternative hay or combining the hay with straw (up to 30% of the forage ration) would be advised. Where a resistance to weight loss is apparent, forage intake may need to be reduced below 1.5% of body weight (target or current) in dry matter. In these instances, veterinary and nutritional input is advised.

Efforts to extend 'chew time' by physically staggering feeding of hay and/or using slow feeders (providing this does not lead to frustration) is recommended both to occupy the horse and to reduce substantial peaks in blood glucose and insulin.

Longer term considerations:

Reintroduction of grass may be warranted once body weight and condition is decreased (ideally to 'lean', body condition score 3–4/9) and insulin dysregulation parameters improved (with veterinary involvement to assess insulin concentration). For some, re-introduction may not be feasible. For the majority, it is possible, but it should be appreciated that ultimately the horse itself has not changed and if exposed to the same conditions and environment, risk of laminitis may still be high. Grass intake would need to be restricted on an ongoing basis and insulin dysregulation monitored.

are low in starch and sugar and can be fed in large quantities alongside a balancer to provide additional calories (Geor, 2010).

Forage

As the basis of the diet, forage (hay, haylage, pasture) will represent the majority of the ration, so management and selection of forage is key to the management of laminitis. Arguably, this part of the ration is the most challenging to control and manage, as many owners do not have the facilities or flexibility to procure or manage their own forage.

The ration should be based on long-stem forage that is low (<10–12% dry matter) in non-structural carbohydrates and high in fibre (neutral detergent fibre 60-65%; acid detergent fibre 35–45%) and, where weight loss or control is required, low in calories (energy) (≤8MJ/kg digestible energy). Sourcing an appropriate (typically mature) forage will allow for more volume to be fed, helping to satisfy hunger, while also aiding weight loss where required (Geor, 2010; Rendle et al, 2018). While hay or haylage arguably may meet these requirements, hay can provide greater flexibility with the option of soaking and, tending to be less palatable, may occupy the horse for longer (Müller and Uden, 2007; Martinson et al, 2012).

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) and while this analysis appears to be generally indicative of wet chemistry, disparity has been reported of within bale sugar levels (across analysis methods) which warrants further research (Harris et al, 2018). At this time, the focus should be on obtaining consistent forage, maintaining good producer/supplier communication, awareness of analysis method of sugars (Longland and Byrd, 2006) and, where possible, conducting representative sampling for analysis.

In the absence of analysis, or where appropriate forage cannot be procured, soaking hay to leach sugars or combining up to 30% of the forage ration with straw is recommended (Harris et

KEY POINTS

- Prevention and management and ultimately welfare of the laminitis prone horse or pony is heavily reliant on strong working relationships between the horse owner, vet and related paraprofessionals. A holistic 'team' approach is key to both prevention and management.
- The main focus of the complementary ration for the laminitic should be to balance the ration when fed alongside an appropriate forage. Common options include, a balancer, a broad-spectrum vitamin and mineral supplement or fortified chaff.
- Careful selection and management of forage for the laminitc is essential and should be the basis of nutritional management. This can often be a key barrier in the implementation of appropriate rations for laminitics. The aim should be to provide a forage which has 10–12% non-structural carbohydrates on a dry matter basis. Where this is not possible, soaking the hay for up to 12 hours or combining with straw (30% of ration) to reduce non-structural carbohydrate content overall is recommended.
- The addition of grass pasture in any ration adds an element of conjecture and therefore careful management is vital. Pasture restriction options include strip grazing, muzzles, dry lots and track systems. However, further research on grazing strategies and their implementation is required.

al, 2017; Rendle et al. 2018; Dosi et al, 2020). Wherever possible, long-fibre should be prioritised to promote 'chew-time' and natural behaviours.

Pasture

Grass intake is difficult to estimate and regulate. For some, complete removal of pasture from the ration is necessary, and this can allow for more control. Where significant weight loss is required, programmes that exclude pasture appear to encourage greater losses (Gill et al, 2016).

For horses with a predisposition to laminitis (through history or metabolic issues), it is important to consider that even if body condition and weight is well managed, pasture management to limit sugar intake is still key (Karikoski et al, 2011, 2016; de Laat et al, 2019a; Durham et al, 2019).

Options for pasture restriction are often informed by facilities and other practicalities, meaning that there is no universal recommendation (Furtado, 2021a, 2012b). As such, trial and error is often required to find a solution that works for both the horse and carer. Options include strip grazing, grazing muzzles, stabling, dry lots (grass free turnout) and track systems based around innovative resource placement (Cameron et al, 2021; Furtado et al, 2021b).

In addition to this, timing and location of pasture access can be approached tactically, to promote consumption in situations where sugar accumulation may be reduced. Knowledge of environmental conditions which result in lower levels of sugars within grass can be instrumental in day-to-day management:

- Lower light intensity reduces plants' ability to produce sugar (Watts, 2010). As such, turning out on overcast days (Longland and Byrd, 2006), in paddocks shaded by hedges or tress, or in woodland areas can be effective.
- Non-structural carbohydrate concentration typically accumulates throughout the day, dropping a few hours after sunset and beginning to rise again by 10am the next day. As such, turn-out early in the morning can be most appropriate (Longland and Byrd, 2006).
- Avoiding scenarios which may inhibit growth but not photosynthesis, such as drought, lack of nutrients or bright sunny conditions on frosted ground, is key as under these conditions, non-structural carbohydrates have been shown to accumulate (Chatterton et al, 1989; Watts, 2004; Longland and Byrd, 2006; Watts, 2010). Furthermore, conditions in the spring or autumn, where overnight temperatures dip below 5°C, and warmer days also predispose non-structural carbohydrate accumulation (Watts, 2010).

Considerations

Regardless of the restriction method, compensatory grazing (where the horse effectively adapts to consume the same grass intake over a shorter period) should be considered. For pasture restriction to work, any method to limit intake should not be employed alongside free access to grass. Grazing very short pasture (with consistently new growth) can often result in the horse not meeting its minimum fibre requirements (young grass being less fibrous (National Research Council, 2007; Equi-analytical laboratories, 2020). Management with this method should be paired with a conserved forage that is high in fibre. Where grazing is restricted through any means, weekly monitoring by the owner and progress reviews with paraprofessionals (Furtado et al, 2021b), along with regular dental checks, are recommended.

Conclusions

Recent findings emphasise the importance of monitoring weight and condition (Durham et al, 2019; Pollard et al, 2019b), with recent (potentially unintentional and rapid) weight gain being a prominent factor in the development of laminitis. This may also suggest a lack of knowledge and/or incorrect application in weight and body condition monitoring protocols. Owner education in the range of clinical signs and the importance of early intervention is key, along with dissemination of practical aspects of daily management that can be changed to mitigate risk. Studies recommend that owner education should focus on recognition of lameness and digital pulses, and emphasise the importance of clinical history, so that those with a history of laminitis can be managed appropriately. Studies also highlight the importance of a holistic approach to the prevention and treatment of laminitis, with the inclusion of paraprofessionals, such as farriers, in prevention strategies.

While research has equipped professionals with the knowledge required to design appropriate rations for equines predisposed to laminitis, a key barrier remains with the implementation of appropriate forage provision. As such, further research on grazing strategies, appropriate analysis of forage, and management of forage is required, along with a change in perception to disemminate the importance of selecting and managing forage.

Conflicts of interest

The author has no conflicts of interest to declare.

References

Asplin KE, Sillence MN, Pollitt CC, McGowan CM. Induction of laminitis by prolonged hyperinsulinaemia in clinically normal ponies. Vet J. 2007;174(3):530-535. https://doi.org/10.1016/j.tvjl.2007.07.003

Barker WR. Treating laminitis: Beyond the mechanics of trimming and shoeing. Vet Clin North Am Equine Pract. 2012;28(2):441-455. https://doi.org/10.1016/j.cveq.2012.05.004

Cameron A, Harris P, Longland A, Horseman S, Hockenhull J. UK horse carers' experiences of restricting grazing when aiming to prevent health issues in their horses. J Equine Vet Sci. 2021;104:103685. https://doi.org/10.1016/j.jevs.2021.103685

Chatterton NJ, Harrison PA, Bennett JH, Asay KH. Carbohydrate partitioning in 185 accessions of Gramineae grown under warm and cool temperatures. J Plant Physiol. 1989;134(2):169–179

de Laat MA, Sillence MN, McGowan CM, Pollitt CC. Continuous intravenous infusion of glucose induces endogenous hyperinsulinaemia and lamellar histopathology in Standardbred horses. Vet J. 2012:191(3):317–322. https://doi.org/10.1016/j.tvjl.2011.07.007

de Laat MA, Sillence MN, Reiche DB. Phenotypic, hormonal and clinical characteristics of equine endocrinopathic laminitis. J Vet Intern Med. 2019a;33(3):1456–1463. https://doi.org/10.1111%2Fjvim.15419

de Laat MA, Reiche DB, Sillence MN, McGree JM. Incidence and risk factors for recurrence of endocrinopathic laminitis in horses. J Vet Int Med. 2019b;33(3):1473–1482. https://doi.org/10.1111/jvim.15497

Delarocque J, Reiche DB, Meier AD, Warnken T, Feige K, Sillence MN. Metabolic profile distinguishes laminitis-susceptible and -resistant ponies before and after feeding a high sugar diet. 2021;17(56). https://doi.org/10.1186/s12917-021-02763-7

Donaldson MT, Jorgensen AJ, Beech J. Evaluation of suspected pituitary pars intermedia dysfunction in horses with laminitis. J Am Vet Med. 2004;224(7):1123–1127. https://doi.org/10.2460/javma.2004.224.1123

Dosi MCM, Kirton R, Hallsworth S, Keen JA, Morgan RA. 2020. Inducing weight loss in native ponies: is straw a viable alternative to hay? Vet Rec. 2020;187(8):E60. https://doi.org/10.1136/vr.105793

Durham AE, Frank N, McGowan CM et al. ECEIM consensus statement on equine metabolic syndrome. J Vet Intern Med. 2019;33(2):335–349. https://doi.org/10.1111/jvim.15423

Equi-analytical laboratories. Common feed profiles. 2021. https://equi-analytical.com/common-feed-profiles/interactive-common-feed-profile/ (Accessed 6 January 2022)

Furtado T, King M, Pinchbeck G. The use of alternative grazing systems in the UK. 2012a. https://www.liverpool.ac.uk/media/livacuk/equine/documents/The,use,of,alternative,grazing,systems,in,the,UK.pdf (Accessed 6 January 2022)

Furtado T, Perkins E, Pinchbeck G, McGowan C, Watkins F, Christley R. Exploring horse owners' understanding of obese body condition and weight management in UK leisure horses. Equine Vet J. 2021b;53(4):752–762. https://doi.org/10.1111/evj.13360

Galantino-Homer H, Brooks SA. Genetics and signalling pathways of Laminitis. Vet Clin North Am Equine Pract. 2020;36(2):379–394. https://doi.org/10.1016/j.cveq.2020.04.001

Gardner AK, van Eps AW, Watts MR, Burns TA, Belknap JK. A novel model to assess lamellar signalling relevant to preferential weight bearing in the horse. Vet J. 2017;221:62–67. https://doi.org/10.1016/j.tvjl.2017.02.005

Geor R. Nutrition and exercise in the management of horses and ponies at high risk for laminitis. J Equine Vet Sci. 2010;30(9):463–470. http://doi.org/10.1016/j.jevs.2010.07.011

Gill JC, Pratt-Phillips SE, Mansmann R, Siciliano PD. Weight loss management in client-owned horses. J Equine Vet Sci. 2016;39:80-89. https://doi.org/10.1016/j.jevs.2015.12.014

Harris PA, Ellis AD, Fradinho MJ et al. Review: Feeding conserved forage to horses: recent advances and recommendations. Animal. 2017;11(6):958–967. https://doi.org/10.1017/s1751731116002469

Harris PA, Nelson S, Carslake HB et al. Comparison on NIRS and wet chemistry methods for the nutritional analysis of haylages for horses. J Equine V Sci. 2018;71:13-20. https://doi.org/10.1016/j.jevs.2018.08.013

Karikoski NP, Horn I, McGowan TW. The prevalence of endocrinopathic laminitis among horses presented for laminitis at a first opinion/referral equine hospital. Domest Anim Endocrinol. 2011;41(3):111–117. https://doi.org/10.1016/j.domaniend.2011.05.004

Karikoski NP, Patterson-Kane JC, Singer ER, McFarlane D, McGowan CM. Lamellar pathology in horses with pituitary pars intermedia dysfunction. Equine Vet J. 2016;48(4):472–478. https://doi.org/10.1111/evj.12450

Langner K, Blaue D, Schedlbauer C, Starzonek J, Julliand V, Vervuert I. Changes in the faecal microbiota of horses and ponies during a two-year body weight gain programme. PLoS ONE. 2020. https://doi.org/10.1371/journal.pone.0230015

Leise BS, Watts M, Tanhoff E, Johnson PJ, Black SJ, Belknap JK. Laminar regulation of STAT1 and STAT3 in black walnut extract and carbohydrate overload induced models of laminitis. J Vet Intern Med. 2012;26(4):996–1004. https://doi.org/10.1111/j.1939-1676.2012.00944.x

Longland AC, Barfoot C, Harris PA. Effect of period, water temperature and agitation on loss of water-soluble carbohydrates and protein from grass hay: implications for equine feeding management. Vet Rec. 2014;174(3):68. https://doi.org/10.1136/vr.101820

Longland AC, Byrd BM. Pasture nonstructural carbohydrates and equine laminitis. J Nutr. 2006;136(7):2099S-2102S. https://doi.org/10.1093/jn/136.7.2099s

Luthersson N, Mannfalk M, Parkin TDH, Harris P. Laminitis: Risk factors and outcome in a group of Danish horses. J Equine Vet Sci. 2017;53:68–73. http://doi.org/10.1016/j.jevs.2016.03.006

Martinson KL, Hathaway M, Jung H, Sheaffer C. The effect of soaking on protein and mineral loss in orchardgrass and alfalfa hay. J Equine Vet Sci. 2012;31(12):776–782. https://doi.org/10.1016/j.jevs.2012.03.007

Meier AD, de Laat MA, Reiche DB et al. The oral glucose test predicts laminitis risk in ponies fed a diet high in non-structural carbohydrates. Domest Anim Endocrinol. 2018a;63:1–9. https://doi.org/10.1016/j.domaniend.2017.10.008

Meier AD, Reiche DB, de Laat MA, Pollitt CC, Walsh D, Sillence MN. The sodium-glucose co-transporter 2 inhibitor velagliflozin reduces hyperinsulinemia and prevents laminitis in insulin-dysregulated ponies. PLoS ONE. 2018b. https://doi.org/10.1371/journal.pone.0203655

Menzies-Gow NJ, Katz LM, Barker KJ et al. Epidemiological study of pasture-associated laminitis and concurrent risk factors in the south of England. Vet Rec. 2010;167(18):690–694. https://doi.org/10.1136/vr.c5177

Menzies-Gow NJ, Stevens K, Barr A, Camm I, Pfeiffer D, Marr CM. 2013. Severity and outcome of equine pasture-associated laminitis managed in first opinion practice in the UK. Vet Rec. 2013;167(10):364–369.

Moore-Colyer M. Effects of soaking hay fodder for horses on dust and mineral content. J Anim Sci. 1996;63(2):337-342. https://doi.org/10.1017/S1357729800014892

Müller CE, Nostell K, Brojer J. Methods for reduction of water soluble carbohydrate content in grass forages for horses. Livest Sci. 2016;186:46-52. https://doi.org/10.1016/j.livsci.2015.06.011

Müller CE, Uden P. Preference of horses for grass conserved as hay, haylage or silage. Anim Feed Sci Technol. 2007;132(1-2):66–78

National Research Council. Nutrient requirements of horses. Washington (DC): National Academies Press; 2007.

Orefice J, Carroll J, Conroy D, Ketner L. Silvopasture practices and perspectives in the Northeastern United States. Agroforest Syst. 2016;91:149–160. https://doi.org/10.1007/s10457-016-9916-0

Patterson-Kane JC, Karikoski NP, McGowan CM. Paradigm shifts in understanding equine laminitis. Vet J. 2018;231:33–40. https://doi.org/10.1016/j.tvjl.2017.11.011

Pollard D, Wylie CE, Newton JR, Verheyen KLP. Incidence and clinical signs of owner-reported equine laminitis in a cohort of horses and ponies in Great Britain. Equine Vet J. 2018;51(5):587-594. https://doi.org/10.1111/evj.13059

Pollard D, Wylie CE, Newton JR, Verheyen KLP. Factors associated with euthanasia in horses and ponies enrolled in a laminitis cohort study in Great Britain. Prev Vet Med. 2019a;174:104833. https://doi.org/10.1016/j.prevetmed.2019.104833

Pollard D, Wylie CE, Verheyen KLP, Newton JR. Identification of modifiable factors associated with owner-reported equine laminitis in Britain using a web-based cohort study approach. BMC Vet Res. 2019b;15(59). https://doi.org/10.1186/s12917-019-1798-8

Potter SJ, Bamford NJ, Harris PA, Bailey SR. Incidence of laminitis and survey of dietary and management practices in pleasure horse and ponies in south-eastern Australia. Aust Vet J. 2017;95(10):370–374. https://doi.org/10.1111/avj.12635

Rendle D, McGregor Argo C, Bowen M et al. Equine obesity: current perspectives. UKVE. 2018:2(Sup5). https://doi.org/10.12968/ukve.2018.2.S2.3

van Eps AW, Burns TA. Are there shared mechanisms in the pathophysiology of different clinical forms of laminitis and what are the implications for prevention and treatment? Vet Clin North Am Equine Pract. 2019;35(2):379–398. https://doi.org/10.1016/j.cveq.2019.04.001

van Eps AW, Pollitt CC. Equine laminitis induced with oligofructose. Equine Vet J. 2006;38(3):203–208. https://doi.org/10.2746/042516406776866327

Watts K. Forage and pasture management for laminitic horses. Clin Tech Equine Pract. 2004;3(1):88–95. http://doi.org/10.1053/j.ctep.2004.07.009

Watts K. Pasture management to minimise the risk of equine laminitis. Vet Clin North Am Equine Pract. 2010;26(2):361–369. https://doi.org/10.1016/j.cveq.2010.04.007

Welsh CE, Duz M, Parkin TDH, Marshall JF. Prevalence, survival analysis and multimorbidity of chronic disease in the general veterinarian-attended horse population of the UK. Prev Vet Med. 2016;131:137–145. https://doi.org/10.1016/j.prevetmed.2016.07.011

Welsh CE, Duz M, Parkin TDH, Marshall JF. Disease and pharmacologic risk factors for first and subsequent episodes of equine laminitis: a cohort study of free-text electronic medical records. Prev Vet Med. 2017;136:11–18. https://doi.org/10.1016/j.prevetmed.2016.11.012

Wylie CE, Collins SN, Verheyen KLP, Newton JR. Risk factors for equine laminitis: a case-control study conducted in veterinary-registered horses and ponies in Great Britain between 2009 and 2011. Vet J. 2013;198:57–69. https://doi.org/10.1016/j.tvjl.2013.08.028