Chapter 3

NUTRITION AND WELFARE

N. DAVIDSON and P. HARRIS
Equine Studies Group, WALTHAM Centre for Pet Nutrition, Freeby Lane, Waltham-on-the-wolds, Leicestershire LE14 4RT, UK

Abstract. The horse is a social species living in herds and spending the majority of its time roaming and foraging in a diverse and seasonally-varying environment. As a non-ruminant herbivore it is well suited to a high fibre, low starch diet. Domestication has resulted in a number of benefits to the horse, reflected in its continued prevalence and apparently increased life expectancy, but it has not been without its price. Especially in developed countries, horses kept for leisure purposes (which includes all competition and racing horses) are often confined, possibly away from conspecifics, within a stable for a large proportion of the day. Due to increased energy requirements many horses now receive one to two large meals a day, consisting of feedstuffs with a low water content and often a radically different nutritional profile from the diet that they would be able or would choose to select in the wild. These modern practices have benefits but also potential disadvantages to the horse both nutritionally and behaviourally which may have an impact on welfare. This chapter highlights areas where dietary imbalances or inappropriate feeding practices may potentially have an adverse effect on welfare and gives suggestions on how these may be ameliorated.

1. Introduction

Since the horse was first domesticated, it has been kept for a variety of purposes including for meat, as a means of transport and for leisure pursuits. This variability still exists today, depending especially on the type of horse and where it is to be found in the world. The way horses are kept and managed also varies considerably both within and between countries and reflects the purpose for which they are kept, where they are kept, what is available, the time of year, their breed/age, as well as the owner's financial situation (Harris 2000). In order to assess whether current feeding practices potentially have a positive or negative effect on welfare, it is important to determine what we are comparing them with. For example our improved knowledge of nutritional requirements, along with our increased knowledge of veterinary medicine, contributes to the fact that many horses today, overall, may be healthier for longer than either their wild ancestors or horses at the beginning of the last century. However, many of our modern management practices (*e.g.* feeding large amounts of cereals in a small number of meals) have a potentially negative impact, and may be compromising today's horses in ways not associated with their ancestors.

It is always important to remember that compared with the horse in the wild, we are now responsible for both our horse's diet and the effect that it may have on health and behaviour. This chapter will discuss some of the major areas of nutrition, which have the potential to affect welfare negatively.

N. Waran (ed.), The Welfare of Horses, 45–76.

2. Natural Diet and Feeding Behaviour

In order to understand the influence that modern feeding and management practices may have, it is helpful to consider the natural diet and feeding behaviour of the horse. The modern horse evolved essentially as a plains dweller, ranging up to 80km per day and exploring and roaming over wide open spaces. Horses do not ruminate and are often referred to as ‘trickle feeders’ (Harris 1999a) as they naturally ingest relatively small amounts of feed at each bite, take a few bites and then chew. They will then move and start the cycle of biting and mastication again. They tend not to eat a discrete meal from one plant or to concentrate solely upon one species of plant, even if it is a preferred plant species (Mariner 1980). The diet of free ranging horses has been shown to be very varied, both on a daily basis and from season to season (Hansen 1976; Ralston 1984; Gill 1988) and because of this, the feeding behaviour of free ranging horses has been thought to be more complex than its stabled counterpart (Carson & Wood-Gush 1983). Although horses prefer to graze, New-Forest ponies take up to 20% of their diet as browse species even at the peak time for grass (Putman *et al.*, 1987; Gill 1988). Similar findings were seen with some American feral horse populations (Hansen 1976).

Horses on managed pastures still show some species preferences (Archer 1971, 1973), although the preferences found in one study are not necessarily confirmed in others and this will reflect the species available, time of year and the methodologies employed (Archer 1978; Avery 1996; Nash 2001). The nature of the pasture affects the amount that is ingested with every bite, with more herbage being ingested with dense high leaf to stem ratio. In order to compensate for a reduced quality of pasture horses, have been shown to increase both their grazing time and their bite frequency (Rolgalski 1970; Nash & Thompson 2001). Whether free-living or domesticated, horses tend to spend around 16–18 hours out of every 24 hours foraging, depending on the type of grazing available (Avery 1996; Nash & Thompson 2001). They rarely fast voluntarily for more than 4 hours at a time. Both stabled and free ranging horses spend a significant amount of their time foraging at dawn, dusk and night (Tyler 1972; Ruckebusch *et al.*, 1976).

3. The Digestive System

The horse’s digestive system is well suited to its almost continual intake of forage (‘trickle feeding’). An overview of the digestive process in the horse, and how diet may influence it, is given below (for further details see Lewis 1995; Frape 1998; Harris 1999a).

The horse selects its preferred food items using its prehensile lips, tongue and teeth. The jaw movements involved in chewing are complex and incorporate both lateral and vertical components. It has been estimated, that (in a 500 kg horse) the jaw makes over 50,000 complete movements a day when grazing. The jaw movements at grass are relatively wide and long but when eating hay, and in particular cereals or pelleted feeds, the movement is confined. The nature of the feeds fed will therefore dramatically influence the chewing rate and speed of ingestion. The horse does not salivate at the sight of food, only producing saliva while it is actually chewing. The more a food item is required to be chewed, the more saliva that is produced and mixed with the feed, which in turn makes the bolus more moist (thus lubricating its passage to the stomach).

The stomach volume of the adult horse (500 kg bodyweight) is relatively small, around 9–15 litres. The stomach is relatively inelastic and has a finite capacity. The musculature is such that vomiting or gastric reflux is extremely rare and usually reflects a significant abnormality. The rate of gastric emptying is largely dependent on the square root of the volume, so that the larger the meal, the more rapid the rate of gastric emptying and the faster the food passes through the small intestine.

The stomach is divided into two sections, which have both anatomical and physiological differences. Food enters from the oesophagus into the cranial non-glandular section where bacterial fermentation of the ingested feed starts. This mainly involves lactobacteria, which convert any available simple sugars or starches to lactic acid. This microbial activity and degradation is stopped when the gastric contents pass to the fundic gland region and mix with the acid stomach juice. When large concentrate meals are fed, the swallowed bolus has a high dry matter (DM) content and the stomach contents therefore also have a higher DM content than if the horse was grazing. This results in slower and /or reduced mixing of the feed with the gastric juices and may allow the survival of, in particular, gas-producing bacteria (Meyer *et al.*, 1975; Harris 1999b). This increases the risk of disturbances due to fermentation and increased gas production. Whether this results in a clinical or sub-clinical problem will depend on the actual amount eaten and the rate of intake, the amount of available sugars and starches and the microbial population.

The basic digestive processes of the small intestine (enzymatic degradation of proteins, fats, starches and sugars) are similar to those of other monogastric animals *but* the activity of some of the enzymes in the chyme, in particular amylase, is less than in other monogastric animals. The horse, therefore, has a limited capacity to digest starch but a comparatively high capacity to digest sugars in the small intestine (Cuddeford 1999a).

Large starch or sugar based meals may overwhelm the digestive capacity of the stomach and small intestine, leading to the rapid fermentation of the grain carbohydrate in the hindgut and a decrease in pH. A significantly decreased caecal pH may initiate a chain of events, which include a change in the microbacterial flora (excessive growth of those bacteria that can live under such conditions), lysis of those bacteria which cannot live at such low pH, allowing the release of endotoxins and other molecules, as well as damage to the mucosa of the caecum and colon. This in turn may allow the absorption of endotoxins and various other materials with potential clinical consequences, including colic, diarrhoea and laminitis (Frape 1988; Clarke *et al.*, 1990; Lewis 1995; Harris 1999a). Hay or roughage based diets do not result in such decreases in caecal pH (Willard *et al.*, 1977) but may not provide sufficient net energy for many horses' needs (Harris 1997a).

There are large fluid movements associated with food digestion. Chewing and consequent salivation result in fluid being drawn from the circulating blood. In horses that chew slowly this fluid can easily be compensated for but in the avaricious feeders the changes in the circulating plasma can be fairly marked and equivalent to those found with dehydration. Restoration may take up to a few hours. This is one of the reasons why encouraging a moderate intake rate is desirable and also why exercising horses soon after a large meal may not be ideal. More than 100 litres of fluid may be secreted into the pre-caecal section of the gastrointestinal tract per day in a typical 500 kg horse. In addition, in discrete meal-fed horses large volumes of fluid are initially secreted into the hind gut as the chyme from the small intestine reaches there, followed by a period of resorption. In horses fed in a more natural way, *i.e.* as trickle feeders, the fluid shifts are much less marked in the hindgut and there are also far less marked fluctuations in the hind gut microflora. The horse relies heavily on sweating for thermoregulation in high temperatures and during exercise and unwanted nitrogen has to be removed as urea in the urine, which also requires water. These together with the large fluid secretions into the gastrointestinal tract help to explain why a constant supply of clean water is essential for the horse.

4. Current Management Practices

Few horses in the developed world are kept today for agricultural purposes or for transportation. Most are kept fundamentally for leisure purposes and two major factors influence their management. Firstly whether they are kept inside in stables/barns or outside on pastures, paddocks or dry-lots and secondly their energy requirements (see Harris 2000).

In a Scottish survey (Mellor *et al.*, 1997), only 10% of horses were kept permanently out at pasture (~10,000 horses), 29% were stabled most of the time and a further 2% were permanently stabled. In a UK based survey (Anon-BETA 1999), it was estimated that approximately 145,000 horses were kept at grass, all year round. In the riding schools and livery yards 23% of horses that were owned by these establishments were stabled all year and 16% were kept in the open all year, as compared with 29 and 11% respectively of those horses owned by others but kept at livery at these establishments. The most common practice was to keep horses stabled in the winter only.

Most horse pastures in the developed world are managed. Well managed and fenced pastures that are not overgrazed and that contain suitable plant species may be able to provide most if not all of the nutrient needs of the horses which graze them (Avery 1996; Nash *et al.*, 2001). If combined with social groups of conspecifics these can also satisfy many of the behavioural needs of horses as well. Unfortunately many pastures do not reach this ideal and for climatic and geographical reasons will not support the nutritional requirements of all horses throughout the whole year, especially horses that are growing or exercising, even if the pastures are well managed (Avery 1996; Kronfeld *et al.*, 1996, 1998; Nash 2001). Overgrazing and inadequate endoparasitic control can also be detrimental to the health of horses. In the wild, horses roam over large areas but when kept on relatively small pastures and allowed to graze freely, horses will quickly establish patches within the pasture. This will include areas that they use for grazing and large patches that they use for excretion (this applies particularly to mares, fillies and geldings and is different to the dung piling that stallions participate in as marking behaviour). It has been estimated that, on a pasture previously ungrazed by horses, around 25–75% of the available sward may be grazed, depending on the density of stocking, the remainder being used for excretion (Archer 1978). If left unmanaged this habit of pattern grazing by horses can lead to the grazed areas being impoverished, bare and potentially infested with unwanted or even poisonous plants such as ragwort (*Senico jacobaea*). The ungrazed areas become coarse and unpalatable even to cattle and overgrown with weeds. Proper pasture management and in particular faeces removal is vital when horses are kept on relatively small pastures (Avery 1996). Optimum stocking densities will depend on the quality of pasture, but as a general rule of thumb, the recommendation is that at least two acres are provided for the first horse, and an extra acre for every additional horse. Time budgets may be affected according to the nature of the pasture – fillies are much more active when grazed on improved pastures than when on unimproved pastures (Nash & Thompson 2001) as potentially less time is required to be spent grazing.

Pastures established for other herbivores such as cattle, may be equally adverse (although combined cattle and horse grazing is recommended to be beneficial (see Avery 1996) and inadequately fenced and maintained pastures may actually prove hazardous. Stabling horses has the advantage that it provides protection against environmental extremes and ectoparasites, provision for individual feeding or care as required, as well as reducing the risk of accidental damage by other horses. However, by confining horses to a stable we not only restrict their movement and social contact with other horses but also affect their perceived ability to remove themselves from danger.

Domestication, and our increasing demand for horses to perform repeatedly has resulted in energy requirements that, for some horses, are above those able to be provided by their ‘natural’ diet of fresh forage. Cereals provide more net energy than hay, which in turn provides more than twice the net energy of straw (Martin Rosset *et al.*, 1994; Harris 1997a) which has resulted in their inclusion in the diets of many horses (Harris 1997b, 2000). Confinement within a stable is therefore often coupled with the feeding of highly concentrated cereal-based meals a few times a day with limited forage (Harris 1997b). However, the feeding of discrete concentrate based meals is not confined to the stabled horse as many horses out at pasture are still fed concentrates, especially the gestating and lactating mare and growing animals.

5. Welfare Implications

A balanced and appropriate diet is crucial for the optimal health and welfare of any horse. Welfare issues often arise when overt deficiencies and/or toxicities, such as with selenium or vitamin D, occur sometimes through neglect, ignorance or a formulation error (N.R.C. 1989; Lewis 1995; Harkins *et al.*, 1997; Frape 1998). Similarly, the ingestion of poisonous plants (such as ragwort (*Senecio* spp.) and yew (*Taxus* spp.), or feed contaminated with toxic components (such as monensin, which can be included in cattle feed as a growth promoter), or certain fungi/bacteria or their associated toxins (such as the ergot alkaloids produced by an endophyte fungus (*Acremonium coenophialum*) found on fescue, or botulism associated with big bale silage) or insects (such as blister beetles) can affect the horse (Lewis 1995; Harkins *et al.*, 1997; Frape 1998; Knight & Walter 2001). These are outside the scope of this chapter but should always be considered in the wider context of nutrition and health.

As outlined above most horses in the developed world are kept for leisure – some for the individual owner's pleasure or competition purposes, others are part of a commercial enterprise, for example a riding school or a thoroughbred stud. The pressures on each of these different enterprises varies considerably – for the riding school horses must be capable of undertaking many hours of relatively repetitive work with different riders on board – for the thoroughbred stud it may be to raise youngstock for the sales or for racing. The latter can produce its own problems, as weanlings and yearlings are well muscled tend to attract the highest prices at sales, which often encourages the production of 'fat' animals. This may result in health problems in the young animal but may also have carryover effects on its health as an adult. The term 'production disease' is applied to man-made diseases of livestock derived from breeding, feeding and management for high production *e.g.* milk fever, mastitis and laminitis. Certain conditions in the horse, especially Developmental Orthopaedic Diseases (DOD, see below) are considered to be production diseases (Kronfeld 1997). Other relatively new conditions, which have a genetic component, have become prevalent because of the demand for the offspring of the originating animal. The most obvious example of this is the condition of hyperkaleamic periodic paralysis (HYPP, an incompletely dominant single autosomal gene disorder) which appears to have originated as a point mutation in a stallion called 'Impressive' which was in demand because of the type and success of the offspring that he produced (Naylor *et al.*, 1993). Nutrition (providing a low potassium dietary intake) can be used in this particular condition to help reduce the incidence and severity of the episodes (Topliff 1997). Similarly other medical conditions, not necessarily with a primary nutritional aetiology, may be helped by appropriate dietary management. This is the case for Equine Rhabdomylolysis Syndrome (often referred to as 'tying-up') (Harris 1999b).

Managemental practices vary considerably throughout the world and present their own unique welfare issues, for example, Equine Motor Neurone Disease in horses kept on dry-lots with no access to green forage (which is believed to be associated with inadequate Vitamin E intake (Valentine 1997)) or sand colic (see below) for those kept on sandy dry lots or sandy pastures.

Some feeding practices that appear on the surface to be beneficial may have disadvantages. In 1994, Brown and Powell Smith reported that many people in the UK prefer to feed hay on the stable floor which may be considered to be a more natural way of feeding (although horses naturally feed at different heights depending on the grazing and browse available). This was endorsed by Townson's survey of a number of Irish racing stables (Townson *et al.*, 1995) which noted that 57% of the racing stables fed hay from the floor. The disadvantages of hay racks or nets high from the ground have been suggested as including an increased risk of particles getting into the eyes and nose, as well as, feet getting caught in the bars/hay net. As this is not the natural feeding position it has been suggested to adversely affect drainage within the respiratory system, to increase the risk of developing caudal and cranial dental hooks and perhaps to adversely affect muscle and nerve function (Hintz 1997). Hay racks at chest height are thought to have the potential to increase the risk of injuries, decrease the space available within the stable and are costly. However, despite hay feeding on the floor being a more natural feeding posture, it increases wastage by increasing the risk of contamination with faeces and urine, and there is an increased risk of parasite egg ingestion.

Finally it should be remembered that some horses are neither kept in discrete paddocks or horse stables but are kept wherever there is space, even if that is on waste tips or in garages. These animals, such as the urban ponies in Dublin, present unique welfare issues that are outside the scope of this chapter.

6. Optimising Diet and Managemental Practices

The closer a feeding system programme can get to the natural system of feeding, the easier it is to maintain gastrointestinal tract homeostasis. But we have to accept that today it is often not possible to keep all horses in the natural way and still maintain their current role in society. There are, however, a number of relatively simple feeding and management practices that may help reduce the problems associated with current methods of managing horses.

6.1. DENTAL PROBLEMS

Horses adult teeth grow continuously throughout their life, gradually being ground down through chewing fibrous, silica-containing forage as well as the kernels of hard grains. The circular jaw movements undertaken when chewing grasses are wider and produce more even wear across the chewing surface, than when preserved forages are being fed. The movements are even more restricted with grains and manufactured feeds. This smaller movement together with the normal anatomy of the equine head (where the upper dental arcade is wider than the lower), results in sharp edges and hooks developing more quickly on the upper lateral, and lower medial teeth surfaces. This can cause 'quidding' (dropping feed while chewing), lacerations within the mouth, pain and may eventually lead to loss in body condition (Dixon 2000). Most other dental problems, not relating to hooks or general wear and tear, occur early on in life. Some are congenital such as Parrot mouth (where the lower jaw is considerably shorter than the upper jaw) or Sow mouth (the opposite to Parrot mouth and where the upper jaw is shorter than the lower jaw).

Alternatively they may result from an accident or an unwanted stereotypic behaviour such as cribbing or wood chewing. Other oral irregularities may occur which are initially easily correctable but over a period of time the relentless grinding action against the irregularity results in a reshaping of the dental arcade into a much more severe abnormality. In the older horse periodontal disease and decay are relatively common. Indicators of teeth problems include quidding, being reluctant or slow to eat the ration, and 'bit' resistance (Pilliner 1996; Meszoly 2001).

6.1.1. *Reducing dental problems*

A recent study has suggested that dental correction in horses without severe dental abnormalities may not have a major effect on digestive efficiency (Ralston *et al.*, 2001), but clinically it has been reported to be of benefit with respect to weight gain and cessation of quidding in those with more severe abnormalities (Dixon 2000). Horses teeth should be regularly checked by a veterinarian, perhaps as frequently as every 6 months, depending on the individual horse and the anatomy of its jaws, the evenness of its dental arcade and its diet. Typically, unless there are known problems, horses between 5 to 15 years of age may only require an annual oral examination whereas younger and older animals, as well as those with problems, will need to be evaluated on a 6 monthly or more frequent basis. In between the regular inspections it is advisable to regularly observe the individual horse's eating pattern so that changes in feeding behaviour can be noted, and it is helpful to be alert to bitting problems. In particular, it can be useful to look out for the presence of any unusual swelling on the upper or lower jaw, excessive salivation, quidding, unusual tilting of the head whilst chewing, unpleasant odour from the mouth or nostril or unusually high amounts of long fibres and grains in the faeces. Catching dental abnormalities in the early stages is preferable to dealing with the long term consequences.

6.2. CHOKE

The typical DM content of a swallowed grass bolus is around 11%, that of a hay bolus is around 20%, whereas that of a cereal-based feed bolus is more like 30–40%. The occurrence of oesophageal obstructions (choke) depends not only on the swelling capacity of the feedstuff but also the speed of feed intake and the size, nature and DM content of the boluses swallowed. Choke has been said to be most commonly due to impaction with pieces of sugar beet, apple or carrots or pelleted/heavily processed feed (Feige *et al.*, 2000). The risk is thought to be increased in horses, which are unable to chew adequately due to old age or poor dentition, or those, which bolt their feed. These factors can be assisted by appropriate management practices.

6.2.1. *Reducing the risk of choke*

The grinding of whole grains is necessary for their optimal digestion in the small intestine. The intensity of the grinding of the roughage may be important for the passage of digesta through the ileocaecal-colic junction into the large intestine.

Therefore, regular dental care is essential to maintain optimal mastication, and consequently optimal digestion. Steps should be taken to prevent horses from bolting their food, which include (Hintz 1994):

- Adding short chopped fibre or chaff (> 2 cm in length);
- Feeding smaller meals more frequently;
- Spreading the feed thinly over a large surface;
- Feeding nervous horses first;
- Adding large, smooth, stones to the feeding trough;
- Splitting the meal into many small compartments within the feeding trough or manger area;
- Using coarse mixes or extruded feeds rather than pelleted feeds.

Lawn clippings or other fine grasses, should be avoided as well as indigestible fibres including corn cobs, twigs, and very mature stemmy forage especially for those horses that are prone to choke or have reduced ability to chew adequately. Sugar beet should be well soaked and each animal allowed to eat the meal at its own pace and pattern (Marie 1999).

6.3. GASTRO-INTESTINAL DISTURBANCES

The rapid digestion of a concentrated meal has been shown to cause distinct physiologic disturbances when compared with grazing or steady state feeding conditions (Williard *et al.*, 1977; Clarke *et al.*, 1990; Pagan *et al.*, 1999). These include:

- Fluctuations of plasma glucose and metabolic hormones;
- Postfeeding increases of plasma proteins and osmolarity;
- Activation of the rennin angiotensin -aldosterone system;
- Periods of intense colonic fermentation with induction of transmural fluid secretion and reduced colonic pH.

Such episodic processes have been suggested to contribute to the incidence of digestive disorders in the stabled horse (Clarke *et al.*, 1990; Ralston 1992). Though defined as abdominal pain, colic in horses has increasingly been taken to represent the large group of intestinal diseases which cause abdominal pain, and at least 6 different types of colic have been recognised (including impaction, spasmodic and sand). In some of these conditions diet is not associated with the patho-physiology but it is frequently incriminated as the major causative factor. The exact relationship between colic and diet is difficult to determine because of the variety of feeds and feeding practices used throughout the world, as well as differences in the study populations. In addition, it is difficult to separate the effects of diet and feeding schedule from other management practices depend on the horse's breed and use. However, in one prospective study in Virginia in the USA, colic incidence was low in horses on pasture who were receiving no grain. The incidence of colic increased as the amount of concentrates fed increased, with those receiving more than 5 kg of concentrates per day being over six times more likely to develop colic than horses receiving no concentrates (Tinker *et al.*, 1996; Tinker *et al.*, 1997).

The colic risk became significant in this study when more than 2.5 kg of concentrates were fed per day. The type of concentrate fed appeared significant, with problems being particularly associated with the processed feed and pellets. Dividing large concentrate meals into several meals a day did not reduce the colic risk, in fact feeding twice daily increased the risk of colic relative to feeding once daily or feeding 3 or more times (but this may be related to the size of each respective meal). In another prospective, case control study in Texas, neither the amount or type of concentrate fed was associated with the colic risk although the researchers did conclude that horses at pasture may have a decreased risk of colic (Cohen *et al.*, 1999). Here changes in diet and in particular the type of hay fed (including hay from a different source or cutting of the same type of hay) were the key risk factors (Cohen *et al.*, 1999). In this study feeding hay other than coastal Bermuda or alfalfa significantly increased the colic risk but this may have reflected hay quality and digestibility rather than type of hay *per se*. Changing to a poorer quality, less digestible, hay or feeding wheat straw or cornstalks may predispose horses to large colon impaction regardless of the type of hay being fed (Hintz 1994; Cohen *et al.*, 1999; King 1999).

A horse that is fed excessive cereal starch or a meal that is too large or experiences a sudden change in diet (of either volume or composition), may suffer from hindgut acidosis. This can also be caused by excessive intake of rich grass that is high in water-soluble carbohydrates (*i.e.* simple sugars as well as the more complex storage carbohydrate: fructans) usually found in larger quantities during the spring and autumn. In a practitioner- based colic study in the UK, a recent change in management was associated with at least 43% of the cases of spasmodic or mild undiagnosed colic. The most common management change was turnout onto lush pasture in the spring (Proudman 1991). The ingestion of high concentrate and low forage diets has also been implicated in the development of gastric ulcers, which in turn may result in signs of colic (Murray *et al.*, 1996).

Miniature horses are particularly susceptible to small colon impaction and it has been suggested that hay quality suitable for other horses may not be sufficient for miniatures. This breed commonly has dental problems, which might be a contributory factor (King 1999). Alfalfa hay may increase the risk of enterolith formation and subsequent colic (King 1999).

Sand colic, the involuntary or voluntary ingestion of sand or small grains of soil, can be seen in particular in horses fed and/or kept on sandy pastures. The sand accumulates in particular at the pelvic and sternal flexures of the large intestine and can cause necrosis of the lining and reduced gut motility (Ruohoniemi *et al.*, 2001). Clinical signs vary but diarrhoea, colic and depression are most commonly seen (Ruohoniemi *et al.*, 2001). Poor nutrition has been implicated, but not confirmed, with the suggestion that a deficient diet may cause horses to seek nutrients from inappropriate sources. Foraging on poor pastures may cause horses to accidentally ingest sand. Studies by Lieb and Weise (1999) indicated that horses may ingest more sand when grain is fed on the ground than when grass hay is fed this way. Others have suggested that more is ingested when alfalfa hay is fed on the ground than grass hay, perhaps due to the alfalfa having a smaller leaf size and being more palatable. Weise and Lieb (2001) however, found no effect of low protein, low energy or combined low protein and low energy diets on sand intake. There was an individual effect, with some horses consuming a mean of 1361 g of sand out of the 2000 g offered. It may be that voracious voluntary sand ingestors may have learned this behaviour from having been kept on poor pastures, but there is no evidence for this. Poor gut motility associated with a high endoparasitic burden may further exacerbate the situation, reducing the transit of sand even more.

In the Texas study, Cohen *et al.* (1999) concluded that whilst a regular programme for administration of anthelminthics might reduce the overall frequency of colic (see also Uhlinger 1990) recent administration of anthelminthics might predispose some horses to colic. Tapeworm infection has been associated with ileal impaction and spasmodic colic in the UK (Proudman *et al.*, 1998). However, other studies do not show such a clear link between parasite control and colic, again probably due to the study groups used, the protocols and the multiple aetiologies of colic.

6.3.1. *Reducing the risk of gastrointestinal disturbances*

It is important to remember that when trying to prevent colic many factors need to be considered, including, but not exclusively, the diet. These include adequate provision of water, maintenance of a regular feeding and exercise schedule, good pasture management, appropriate bedding material and endoparasite control etc.

6.3.1.1. *Forage provision.* Forage (fresh or preserved) should be the foundation of any horse's diet, even those in hard work. Many horses and ponies will not require any other food. Hays with higher energy levels and greater digestibilities should be considered, especially for those animals in competitive work. Those horses in little or no work or those with an especially efficient metabolism (often called 'good doers') may benefit from being fed lower energy-containing roughages but care must be taken that this does not increase the risk of impactions. For the majority of horses, even those in work, at least 50% of their diet on a dry matter basis should be suitable forage (around 1 kg DM/100 kg BW). Even fit, very intensively working horses should be fed at least 35% and preferably 40% of their dry matter (DM) intake as forage. It may be valuable to offer some hay to horses on apparently good pastures, as the fibre content of lush pastures may not be adequate to meet their fibre needs.

Forage type should not be changed rapidly and poor quality forage should be avoided. In addition, items such as lawn clippings, large amounts of rapidly fermentable feeds such as apples, or feeds designed for other types of animals should not be given to horses.

Grain should only be fed when the horse's energy needs cannot be met by forage alone (sometimes small amounts of grain or other concentrates may also be needed to carry supplemental protein or minerals to balance the ration).

6.3.1.2. *Alternative fibre sources.* There has been an increasing interest in the use of alternative energy sources for horses, especially alternative fibre sources which do not cause marked disturbances in the hindgut and provide more energy than typical forages. Sugar beet pulp (SBP) and soya hulls are two such fibre sources. The fibre (non-starch polysaccharide, NSP) in beet pulp is highly digestible over the total tract, with a significant proportion being degraded (approximately 16.5% of unmolassed SBP NSP) in the small intestine during transit to the hind gut (Moore-Colyer *et al.*, 1997; Hyslop 1998). Digestibility studies suggest that not only is SBP well fermented but that degradation occurs to a large extent within the time period that such a feedstuff would remain within the gut (Stefansdottir *et al.*, 1996; Hyslop *et al.*, 1998). Recent studies have shown that sugar beet pulp addition to the diet may increase the nutrient value of concurrently fed hay, especially if this has a low protein content (Moore-Colyer & Longland 2001) and also may have an effect on alfalfa based diets (Hastie & Longland 2001).

6.3.1.3. *Oil.* There is an increasing use of supplementary vegetable oils for horses (Harris 1997a, b) as they provide proportionally more net energy than cereals, yet contain no starch or sugar and may provide other advantages. Although corn oil may be one of the most palatable oil, horses will vary in their preferences and providing the vegetable oil is fresh, not rancid, of a good quality, palatable and digestible to that individual, it may be acceptable. The optimal desired fatty acid composition is not yet known.

Supplemental oil should be introduced slowly since it might result in GIT disturbances. The amount of oil that should be added is still unclear. Horses have been shown to be able to digest and utilise up to 20% or more of the diet as oil. A relationship between dietary fat and muscle glycogen concentration indicated a peak glycogen at 12% oil by weight. A variety of trials have confirmed the value of incorporating this level of oil in a balanced feed (Kronfeld & Harris 1997a). However, adding oil to existing feed has the potential to create multiple imbalances, it is therefore prudent to use less than the 12% suggested above. Levels of 5–8% in the total diet are common in the competition horse. Pagan (1999) recommends 100 g/100 kg BW/day, and the majority of animals (500 kg BW) can be supplemented up to 400 ml/day (~370 g) in divided doses without any problems – provided that the oil has been introduced gradually, is required, is not rancid and the vitamin E levels are considered (Harris 1999b). In order to obtain metabolic benefits from the feeding of oil, in addition to those associated with its high energy density and lack of starch content, the oil needs to be fed for several months (Harris 1997a, Kronfeld & Harris 1997). It is recommended that additional vitamin E be fed in combination with supplemental oil, an additional 100 iu vitamin E/100 ml supplemental oil is suggested (Harris 1999b).

6.3.1.4. *Cereal.* The pre-caecal and even pre-ileal digestibility, the amount being fed, the feedstuff under consideration and the extent and nature of the processing to which it has been subjected will determine glucose and volatile fatty acid production (Kienzle *et al.*, 1992; Kienzle 1994; DeFombelle *et al.*, 2001). Although most people recommend that the amount of starch in each meal should be limited, there are relatively few details of what may be considered to be too large a meal

(Hintz 1994). Feeding, in a meal, around 400 g starch per 100 kg bodyweight has been suggested to saturate the small intestine's digestive capacity for starch (Potter *et al.*, 1992). Feeding less than 300 g starch per 100 kg BW was recommended by another author (Kienzle 1994) and recently it has been suggested that even at this level there may be concerns, depending on the nature of the feed (De Fombelle *et al.*, 2001), since at 300 g starch per 100 kg BW all the oat starch was digested in the small intestine, but 20% of the barley starch and 34% of the corn starch escaped the pre-caecal digestion and reached the large intestine (De Fombelle *et al.*, 2001). This means that, despite corn containing more starch than oats on a weight for weight basis, if corn is fed whole, less actual starch will be digested in the small intestine and more will reach the hindgut. Feeding large amounts of corn starch is more likely to result in a significant decrease in hindgut pH and an increased risk of acidosis than if an equivalent amount of oat starch is fed.

There have been a number of studies that have evaluated the beneficial effect of cooking or micronising cereals such as corn and barley to improve pre-caecal digestibility (Kienzle 1994; Cuddeford 1999c; Mclean *et al.*, 2000). It also has been recommended that if meals high in starch are fed they should be fed separately from the fibre (Cuddeford 1999b). It is therefore worth considering increasing the number of meals/day to three or four rather than having two large cereal-based feeds. If a horse appears to require ever increasing amounts of feed in each of its meals in order to maintain condition and energy, and there is no suspicion of ill health consider

- Increasing the number of meals (whilst keeping down the size of each meal);
- Changing to a feed with a higher energy content;
- Adding oil.

6.3.1.5. *Feed changes.* Rapid or major changes in the amount or type of feed eaten by the horse may cause marked fluctuations in the microbial population of the hindgut. Although the microflora adapts to a degree to whatever diet is being fed, quick changes in their environment may cause gastrointestinal imbalances and may lead to diarrhoea or colic. In the past it has been considered to be much less of a risk with changes in preserved forage but as described above this may not always be true when changing to a less digestible source. Typically changing from one type of forage source to a similar one, causes fewer problems compared with changing from preserved to fresh forage or from a forage-only diet to one with concentrates, but ideally, any changes in the diet should be done gradually. Small changes can be made in a step-wise manner over 3–5 days, while more major changes may require a 2–3 week adaptation period. Changes in amount rather than type are preferable where possible and appropriate. Even in a grain-adapted animal the amount of grain should not be increased by more than 0.5 kg per day (for a 500 kg horse).

6.3.1.6. *Reducing the risk of sand colic.* To prevent sand colic, the horse must not be allowed to ingest any sand! Minimising sand ingestion in some geographical areas can be difficult, but there are a few precautions, which should be taken:

- Always ensure nutrition is optimal and the diet is not deficient.
- Do not graze on bare pastures. If this cannot be avoided then an ample amount of an alternative forage should be provided.
- If forage and feed are fed from the ground, this should preferably be a concrete area.
- Offer grass hay rather than alfalfa hay.
- Follow a regular anthelminthic programme.

For voracious sand ingestors, particularly those prone to colic, there are a number of psyllium or clay-based products which some believe assist in the removal of sand from the gut (Ruohoniemi *et al.*, 2001). However, opinions are divided, and work by Lieb and Weise (1999) found no advantage to sand removal from the GIT of feeding or treating with psyllium, wheat bran or oil at 1.5% BW hay intakes. They also reported that at larger hay intake (2.5% vs 1.5%) the sand moves through more rapidly, suggesting that maximising forage intake may be beneficial.

6.4. CHANGING BODYWEIGHT SAFELY

6.4.1. *Conditioning the underweight horse*

The ideal condition of any horse is dependent on its breed, work, life stage and health (for example, you would not wish to allow a horse with problems with its joints to become over-weight). The sick horse is outwith this chapter, however, there may be occasions when a healthy horse is below its desirable weight, and requires changes to its dietary regimen in order to improve its condition. Assuming that the horse has not been starved, has been on a suitable antihelminthic programme and has no dental problems, the rules for increasing weight are as outlined below. All changes must be made gradually, particularly to horses that are extremely underweight, as rapid introduction of feed may result in death (Kronfeld 1993). The exact protocol to follow will depend on the extent of the starvation (Naylor 1999; Stull *et al.*, 2001) but in extreme cases should start with increasing the forage quantity and quality, ideally for at least 10 days, before introducing concentrates, which can be high fibre cubes to begin with. The horse should be fed at the level to maintain its weight at the midpoint between its current and desired weight. Once this weight has been attained then the feed may be increased gradually to a level which will maintain the horse at the goal weight. Supplementary oil may be beneficially used in the re-feeding programme (Stull *et al.*, 2001). Such a programme of weight increase may take several weeks and care is needed with respect to mineral intake, in particular phosphorus and magnesium, especially in severe cases.

If the horse has trouble with maintaining weight (*i.e.* is a ‘poor doer’), the forage should have a high digestible energy and additional energy in the form of oil rather than grain should be offered. Vitamin and mineral content of the diet should match the energy level, therefore if feeding below recommended levels of concentrates, or adding oil, it may be necessary to add a vitamin and mineral supplement. All of this is based on increasing the amount of digestible nutrients available to the horse. Changes may be required in other management factors such as for example, reducing heat loss through appropriate shelter/rugs.

6.4.2. *Reducing weight*

Ponies, especially pregnant ones, must not be abruptly starved to reduce their body weight or prevented from eating for prolonged periods as they have an increased risk of developing hyperlipaemia under such circumstances. It is much safer to gradually reduce the diet to a half maintenance level, if necessary, than to completely starve a pony for weight loss purposes. Wherever appropriate the diet can be made up to near appetite levels by feeding low energy forages but poorly digested, highly silicated forages such as wheat straw, may cause impaction.

6.5. GASTROINTESTINAL ULCERS

The horse secretes acid into the stomach continuously. Under natural circumstances the saliva produced by the horse whilst grazing, helps to buffer the gastric acid and may help to provide a protective layer for the squamous epithelium. In addition, living under natural conditions encourages the horse to move freely and may assist in the normal movement of stomach contents through the gastrointestinal tract. Unfortunately, modern management practices which include meal feeding, low fibre/high concentrate diets, early weaning and intensive training programmes, help to produce a poorly buffered, acidic environment in the stomach. This results in a high prevalence of gastrointestinal ulcers, particularly in intensively-managed horses, such as performance horses (Bertone 2000). The prevalence and severity of ulceration has been correlated with the intensity of training that the horse undergoes and the associated management practices. Murray *et al.* (1996) found that 93% of Thoroughbred racehorses had gastric ulcers, but this percentage varied with the training – two-year olds at the start of training showed no or minimal lesions, but after only 2–3 months of intensive training 90% showed lesions (Murray, unpublished data from Orsini, 2000). Contributing factors associated with lesions are high concentrate diets, low hay diets, meal feeding, fasting, training (which increases gastrin levels) and certain drugs. In addition, the stressful lifestyle of such performance horses is thought to exacerbate these conditions. By comparison, horses that undergo less intensive or no training, or even a different type of training, show a far lower prevalence, *e.g.* 37% in pleasure horses (Murray *et al.*, 1989), and up to 40% in Western performance Quarter Horses (Bertone 2000). GIT ulceration is not isolated to adults, but is prevalent in foals, with up to 51% of foals aged less than 3 months showing lesions (Murray *et al.*, 1989). Foals are highly susceptible to ulceration because they start secreting gastrin just after birth before the gastric mucosa have fully developed (Sandin *et al.*, 2000). In addition, stressful weaning programmes may exacerbate the development of GIT ulcers. Clinical signs of gastrointestinal ulcers include abdominal discomfort, reduced appetite, weight and body condition loss, diarrhoea, and particularly in foals, a loss of vitality, dorsal recumbency, grinding of teeth. The onset of crib-biting may indicate the presence of gastric lesions (Nicol *et al.*, in press).

6.5.1. *Risk reduction*

Preventing the onset of gastrointestinal ulcers should be a priority, and this can usually be achieved by keeping adult horses at pasture. However, as this is not possible for all horses, other steps often need to be taken. There is a strong correlation between the diet fed and the pH of the stomach. Concentrate diets have always been implicated but ensuring these are fed in small amounts, possibly in combination with a forages such as alfalfa hay may help to increase the stomach pH and volatile fatty acid content in gastric contents (Nadeau *et al.*, 2000). A high forage intake that encourages chewing and stimulates salivation should be maintained. If lesions do occur, training should be reduced or stopped until the lesions have healed. Wherever possible and especially in a horse with known predisposition to this problem, stressful situations such as travelling long distances, changing environment and long periods of confinement where the horse cannot freely move around should be avoided. There are a number of pharmaceutical agents that can be used in consultation with the veterinarian. These work by preventing or reducing the secretion of gastric acid and therefore increasing gastric pH, coating the mucosa or introducing endogenous prostaglandins, but they should ideally be viewed as a short-term measure to resolve the lesions while changes in management practices take effect. Omeprazole paste may be the most safe and effective anti-ulcer therapy to use in horses which continue to be trained and raced (Johnson *et al.*, 2001).

6.6. LAMINITIS

Laminitis has been recognised as a clinical disorder since the 19th century. It is currently thought to represent an end stage condition, common to a number of disease processes, which results in destruction of the interlaminar bonds of the hoof. If severe this may allow independent movement of the pedal bone with respect to the hoof wall (Howarth 1992). The laminae consist of interlocking finger-like projections that are separated by nerves and blood vessels (see Figure 1). It is these blood vessels that supply the hoof. The laminae hold an integral part in the construction of the hoof wall by providing strength and stability to the structure as a whole. The force created by the horse's weight is passed down through the bones of the leg to the top of the pedal bone (3rd Phalanx or P3), which is locked within the hoof wall. The laminae effectively connect the outside of the pedal bone to the inside of the hoof wall, transferring the force from one to the other, thus, distributing the horse's bodyweight over a much larger surface area.

Laminitis can affect any horse but there appears to be an increased incidence in overweight animals, small to medium size horses and in particular ponies. There are many potential causes. Certain episodes result as a consequence of a primary disease or condition elsewhere in the body, for example retained placenta, an endocrine imbalance (*e.g.* Cushings) or certain toxaemias.

Ralston (1992) stated that 'overall the reliance on oropharyngeal stimuli, lack of attention to gastrointestinal or metabolic feedback during the course of a meal in conjunction with relatively slow adaptation to changes in caloric density of feed, make horses prone to excessive intake (gastrointestinal overload) when suddenly

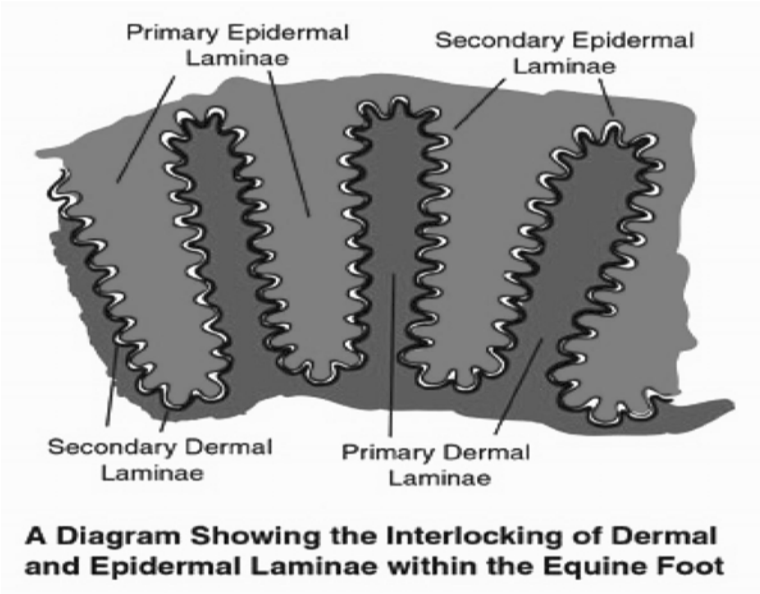

Figure 1. Laminae.

presented with feeds of high caloric density'. Grain overload whether by accident or deliberately induced increases the risk of developing laminitis. For over 50 years it has been known that the administration of a 85% carbohydrate and 15% fibre diet will result in clinical signs of laminitis within 40 hrs, including a pounding digital pulse, tachycardia, pain and a characteristic forelimb lameness (Obel 1948).

Turning ponies out onto lush pastures in the spring and autumn is a common triggering factor for the development of laminitis. Currently it is thought that the high levels of water soluble carbohydrates (which include the simple sugars as well as the more complex storage carbohydrate (fructans) may be involved in this process. It is thought that as for other mammals the horse does not have the necessary enzymes to digest fructans directly within the small intestine. They therefore pass into the hindgut where they are readily fermented in a similar manner to starch that escapes digestion (Cuddeford 1999a). Rapid fermentation will lead to production of lactic acid, and the lowering of pH (acidosis) upsetting the bacterial/microbial balance. When this occurs, bacteria that are not able to survive under such conditions may die and release endotoxins and other unwanted compounds into the hindgut. These endotoxins together with the other unwanted compounds could be absorbed into the blood and have further effects. The blood flow to the feet, is particularly sensitive to some of these factors and results in an inflammatory response, triggering the development of laminitis.

6.6.1. *Nutritional risk factors for laminitis*

Fructan (and water-soluble carbohydrate – WSC) intake should be reduced. The fructan content of grass will vary and is largely dependent on, light intensity, ambient temperature, stage of growth, residual fructan accumulation from the previous day and pasture management regimens (Cuddeford 1999a). It is usually when energy demands upon the plant are high (*e.g.* during growth) that the fructan concentration will be at it's lowest (as it is being utilised to provide energy). Fructan levels are higher in the stem than the leaf as it is a storage carbohydrate (Cuddeford 1999a). It is also known that particular grasses contain a higher concentration than others, for example, cocksfoot and timothy both have a lower level than most perennial ryegrasses. The fructan content of grass is likely to be higher during spring before the development of the flower when the fructans are being stored. In the autumn time, if a low temperature is followed by a bright and warm day the fructan concentration may also increase as the factors mentioned above may not be sufficient to support growth. It is therefore thought that the safest time to turn out may be late at night, bringing the horse in by mid-morning. The fructan content of hay is likely to be lower than that of fresh grass, and will be lower still in haylage due to the fermentation process. There are various practices that are recommended that will reduce the risk of the development of laminitis. These are summarised in Table 1.

Table 1. Recommended practices for reducing the risk of laminitis.

- Horses should only be at pasture when fructan levels are likely to be at the lowest, such as late at night to early morning, removing them from the pasture by mid-morning.
- Horses should not be grazed on pasture that has not been properly managed by regular grazing or cutting. (young leafy sward should be maintained at approximately 4 cm in height and mature stemmy grasses should be avoided since this contains high levels of stored fructans).
- Horses should not be turned out during the spring (before flower development) and autumn months when fructan levels are accumulating and plants generally contain relatively high levels of WSC.
- Horses should not graze pastures that have been exposed to low temperatures (e.g. frosts) with warm, bright sunny weather.
- Horses should not be grazed on freshly cut stubble (after hay has been harvested), as plant stems are the storage organs for fructans.
- For some horses it may be necessary to consider zero grazing (whilst providing the horse with suitable forage).
- If horses are grazed, they should only feed on grasses that produce low levels of fructan (eg. timothy).
- Horses should be fed forage rather than concentrates. Oil could be used in place of starch as an energy source (with veterinary approval) and broad spectrum vitamin and mineral supplements can be used where no (or low levels of) concentrates are fed and if the quality of the forage is poor.
- Horses should be fed according to their energy requirements.
- Horses should have their hooves regularly trimmed or shod.

6.7. RESPIRATORY SYSTEM

Allergic respiratory disease in horses or Recurrent Airway Obstruction (RAO) is more frequently referred to as 'heaves' or Chronic Obstructive Pulmonary Disease (COPD; Lavoie 1997) and is one of the oldest documented diseases of the horse. There is considerable evidence implicating allergic reactions in most affected animals. It is rarely found in tropical or subtropical countries where animals spend most of their time at pasture. In temperate climates COPD is closely associated with housing and the presence of dust and fungal spores in the air (Halliwell et al., 1993). The pathophysiology may be multifactorial, with a lower airways inflammation caused by a hypersensitivity reaction to specific allergens; a non-specific hyper-reactivity reaction or an inflammatory response induced by dust. Two moulds: *A. fumigatus* and *F. rectivirgula* have been most commonly implicated as inciting allergens (Halliwell *et al.*, 1993). COPD can affect up to 50% of horses in some stables resulting in a range of signs from reduced exercise-tolerance to, coughing, mucus hyper-secretion and severe dyspnoea. COPD can affect all types of horses and can be difficult to control especially if the animal is in full work (Andrews & Schemeitzel 1999; Robinson 2001). Some horses develop a similar condition when at pasture (McGorum & Dixon 1999) with no access to hay or straw – Summer Pasture Associated Obstructive Pulmonary Disease (SPAOPD). Some of these will develop classical COPD when exposed to poorly conserved hay/straw. It has been suggested (McGorum & Dixon 1999) that horses with SPAOPD have 'long term airway hyper-responsiveness which results in persistences of inflammation and dysfunction in response to a wide range of specific (*e.g.* mould or pollen allergens) and non specific triggers (*e.g.* cold air, dry air, exercise, irritant dusts).

A number of studies have evaluated the effects of environmental conditions during outbreaks of respiratory disease and one suggested that 'whereas healthy horses may be able to tolerate considerable variations in environmental conditions the presence of dust and other environmental contaminants can substantially extend the convalescent period once horses are affected with respiratory disease' (Burrell *et al.*, 1996). These workers found in their study that those horses housed on straw in loose boxes were twice as likely to suffer from lower airway disease as those kept on shredded paper in American barns.

An additional challenge to the respiratory system may occur for stabled horses due to raised ammonia levels in the stable. Stable hygiene practices and bedding choice will obviously have an effect on this. An additional factor may be diets that provide a higher protein intake than required, as excess protein cannot be stored and the excess nitrogen is removed primarily via urea in the urine. Higher protein intakes result in higher plasma urea concentrations, an increased water requirement and more urea excreted in urine. This urea is then converted by bacteria within the stable environment to ammonia. Lower respiratory tract inflammation can result from exposure to ammonia (Clarke 1987).

Hay quality can be very variable due to unpredictable weather conditions; hay often tends to be dusty with a high fungal spore count, especially the small diameter thermophilic actinomycetes which have been particularly associated with the dust from hay. It is not always possible to confirm the hygienic quality by eye (Raymond *et al.*, 1994). It has been estimated that around 12 million particles may be taken into the lungs of an average stabled horse with each breath and that even in well ventilated buildings the level of airborne particles around the hay and therefore within the breathing zone will still be very high (Blackman & Moore-Colyer 1998). Whilst obviously dusty and mouldy feeds should be avoided for all horses (but especially if they are prone to COPD or SPAOPD) other measures are often needed. There has been an increase in the use of alternative forage sources for horses, in particular big bale haylage (DM > 40%) and silages (< 40% DM). These, if prepared and stored correctly tend to have a better hygienic quality but there may be other concerns, especially with respect to potential clostridial activity and reduced overall fibre intake (in horses).

It has been reported that soaking a 2.5 kg hay net for 30 minutes reduces respirable particle numbers by 88% (Blackman & Moore-Colyer 1998). The practice of soaking hay with the aim of reducing the number of airborne particles is popular in some areas (Blackman & Moore-Colyer 1998; Harris 2000). The water used for soaking must be fresh and, although there is still discussion over exactly how long soaking should be carried out, increasingly it is recommended that more than 30 minutes may not be advisable because of the potential negative effect of prolonged soaking on the soluble carbohydrate and nitrogenous content of hay (Warr & Petch 1992; Blackman & Moore-Colyer 1998). Alternative solutions include the practice of steaming hay. In one study soaking for 10 or 20 minutes reduced the respirable particle numbers but also the concentration of phosphorus, potassium, magnesium, sodium and copper (Blackman & Moore-Colyer 1998). Steaming had a similar effect on the respirable particles but there was no loss of nutrients. However, these authors noted that, although reducing the number of respirable particles may be advantageous to a healthy horse and may help prevent the initiation of this debilitating condition, it may not be sufficient for some sufferers of COPD, in which case vacuum-packed dust-free fodder and pasture turnout would be recommended.

Recent research (Deaton *et al.*, 2001; Marlin *et al.*, 2001) found that ascorbic acid (vitamin C) levels were lower in the lung epithelial lining fluid and plasma of horses with COPD/RAO, compared to those of healthy horses. Further work (ongoing) suggested that lung function of RAO horses in remission could be improved by feeding a cocktail of antioxidants (Kirschvink 2001).

6.7.1. *Management of respiratory diseases*

There are a number of steps that can be taken to improve the environment for horses with RAO which may help to alleviate the condition (Table 2). However the first step should be to gain veterinary diagnosis and advice.

6.8. DEVELOPMENTAL ORTHOPAEDIC DISEASE (DOD)

The term DOD was first coined in 1986 to encompass all orthopaedic problems seen in the growing horse. It is non-specific and currently is taken to include osteochondrosis; subchondral cystic lesions; physitis; acquired angular limb

Table 2. Management to alleviate respiratory problems.

- The affected horse should be turned out as often as possible.
- The stable environment should be well ventilated (as opposed to draughty).
- Deep-litter bedding systems should be avoided.
- Faeces and urine should be removed frequently, and the horse should be moved from the stable before cleaning the bedding or grooming.
- The bedding substrate should provide a reduced allergen challenge and be non-dusty.
- Affected horses should not be housed near to any concentrated source of irritants/allergens such as, deep- litter beds, dung-piles, hay and straw stores.
- Hay should be checked and low dust hay should be fed. Hygienic quality should be checked if possible.
- If hay is fed, it should be soaked as this promotes the swelling of fungal spores so that they may be ingested rather than inhaled. The current recommendation is to soak hay for 30 minutes in clean water. Alternatively, steamed hay or other forage types such as haylage could be fed.
- All other feedstuffs should be of good quality.
- Feeding an appropriate antioxidant supplement formulated for horses should be considered.

deformities; flexural deformities; cuboidal bone malformation; juvenile arthritis or juvenile degenerative joint disease and bony fragments of the palmer/plantar surface of the first phalanx of standardbred horses (believed traumatic lesions) (McIlwraith 2001). Many possible causes have been suggested but in future it may be necessary to differentiate the cause and the triggering factor(s) from any consequent clinical signs. It has been suggested that as far as osteochondrosis is concerned it is most likely that initially some disturbance to the normal cartilage development occurs and then physical stresses are superimposed leading to the clinical signs of Osteochondrosis Dissecans (OCD) (McIlwraith 2001). It is also thought possible that the initial defects/lesions may heal or may develop into OCD or into subchondral bone cysts.

Many causes have been suggested for DOD, including a genetic disposition, biomechanical trauma, mechanical stress through inappropriate exercise, obesity, rapid growth and inappropriate or imbalanced nutrition. It is currently thought to be multi-factorial in origin. With respect to nutrition various nutrients have been implicated over the years but in particular protein, energy, calcium, phosphorus, copper and zinc (Kronfeld *et al.*, 1990; McIlwraith 2001).

There is currently little evidence that protein *per se* is a major factor but too much or the wrong type of energy may be involved in some cases. Feeding 129% NRC energy requirements to foals from 130 days of age resulted in increased incidence of lesions compared with controls or horses fed 126% National Research council's recommendations (NRC 1989) for protein (Savage *et al.*, 1993). It has been suggested that diets or individuals that respond to diets to produce high glyceamic peaks, which in turn cause high insulin peaks and the consequent reduction in the production of thyroxine which affects bone maturation, may have an increased risk of developing DOD (Glade & Belling 1986; Ralston 1995; Pagan 2001). Savage *et al.* (1993) fed three and a half times NRC recommended levels of calcium to 6 foals and found no change in incidence. However, although the incidence of clinical physitis and flexural deformities has not been shown to be related to marginal deficient phosphorus levels, excessive phosphorus intakes appeared to increase the incidence of OCD in unexercised foals – but these intakes were being fed with concurrent high energy intakes (129% NRC) (Cymbulak & Christison 1989).

A copper containing enzyme – Lysly oxidase, is involved in the X-linking of protein chains in elastin and collagen of cartilage. Disruption of these X-links due to copper deficiency may result in biomechanically weakened cartilage and increase the risk of DOD (Hurtig *et al.*, 1993). A number of studies have suggested a relationship between copper and zinc in the diet and DOD (Knight *et al.*, 1985, McIlwraith 2001) but whilst improved diets may have helped some horses, this does not appear to have been universally successful and there may have been an effect of study design on the results. In a series of elegant studies in New Zealand (Pearce *et al.*, 1998) copper supplementation of mares significantly decreased the radiographic indices for physitis in the distal third metatarsal bone of foals at 150 days and the prevalence of articular cartilage lesions. Supplementing the mare did increase the liver copper status but had no effect on other tissue copper concentrations. It is important to note that, unlike many of the US based studies, articular cartilage lesions were minor in all foals with no evidence of clinical OCD *in vivo*, with the exception of minor radiographic changes assessed at post mortem. The differences in the results may reflect other nutritional factors and differences between the US and pastured foals in New Zealand. Copper supplementation of the foal did not have any effect on any of the bone or cartilage parameters measured but the copper intake of the control foals was only mildly deficient.

Excessive zinc has been associated directly with OCD – suggesting that increased exposure to zinc and possibly cadmium may result in the development of OCD.

6.8.1. *Reducing the risk of DOD*

Adequate and balanced nutrition with appropriate exercise for the growing foal is very important and although this will not totally reduce the risk of DOD it might help reduce it. This is paramount as once DOD is evident, the solutions, such as early weaning or confinement, while perhaps being effective at reducing the impact of the disease, severely reduce other welfare aspects of the foal's life.

Steady growth curves should be aimed for, and any spurts are to be avoided. Diets should be nutritionally balanced, preferably avoiding those with high-energy intakes from hydrolysable carbohydrates. It may also be advisable to avoid high protein diets that also provoke high insulin responses. Kronfeld's group at Virginia Tech, USA in particular, have been evaluating the benefits of feeding a fat and fibre rich pasture supplement compared with a more traditional starch and sugar based supplement and have found:

- Smoother growth curves without the spring 'dip' and compensatory surge
- Reduced glycaemic response – more equivalent to that seen at grass
- Less disturbance to the somatatrophic axis (see Hoffman *et al.*, 1999; Stanier *et al.*, 2001; Williams *et al.*, 2001).

Unless severe lesions already exist, exercise may help to modulate the adverse effects of high-energy diets on joint development. Bruin *et al.* (1994) exercised warm-blood foals fed high energy diets (30–45 mins of trot and gallop in a lunging ring several times a day) and found beneficial effects. However, in a recent study exercise was not shown to reduce the number of lesions but it was suggested that it might help reduce the severity (Van Weeren & Barneveld 1999). In conclusion, it is currently recommended that adequate exercise should be provided daily. Excessive strain or trauma to the young horses' growing bones and joints should be avoided. This can be done by avoiding exercise to fatigue/exhaustion and also by avoiding a situation of confinement followed by abrupt turn out, especially on hard ground, as this increases the risk of biomechanical trauma.

Adequate calcium in balance with phosphorus is advisable for the growing animal. Certainly excessive calcium may not be protective and may interfere with the absorption of other elements. Pregnant mares should be fed adequate copper and zinc to allow the foetus to accumulate sufficient stores; therefore, growing foals and pregnant mares should be fed approximately 15–20 mg copper/kg DM. Zinc should be fed at between 3–5:1 (Zn:Cu); optimally at 4:1 Zn:Cu.

7. Nutritional Impact on Behaviour

An inappropriate diet, whether it is a deficiency or an overdose of a specific nutrient or feed type, can be reflected in changes in behaviour. Behaviour which may be considered by an owner to be inappropriate, such as pica/geophagia (McGreevy *et al.*, 2001), wood chewing or copraphagia may be the result of a deficient diet (although in young horses it may also reflect their motivation to investigate and orally manipulate all kinds of substrates).

Obviously, any dietary factor that causes the horse pain, such as rapid or large changes in the amount of concentrates fed, will result in the horse responding differently to its normal environment. Hind-gut acidosis or other gastrointestinal disturbances may not result in the visible symptoms of full blown colic, but the consequences may be apparent as more subtle behavioural changes. The horse may become depressed, cantankerous, show increased sensitivity to touch or just show changes in responsiveness. Changes in activity levels and type may also indicate pain, such as moving less, standing in a manner that suggests tension rather than a relaxed state, or alternatively the horse may become more restless, or display specific behavioural changes, such as constantly turning around to nip its side.

There are many behavioural changes that are recognised symptoms of specific diet deficiencies or toxicities which are too extensive to be covered here; in addition, some behavioural changes may not be linked to diet but to a specific condition or disease. However, it is becoming increasingly recognised that some specific behaviour patterns that once were thought to be due to boredom and were considered to be vices, may be linked to modern management practices, and specifically to diet (although stable confinement is also a major factor). These behaviour patterns tend to be classified as stereotypies and include both oral and locomotory behaviours (see Chapters 4 and 5). Time spent foraging, and also a reduction of appropriate forage given concomitantly with an increase in concentrates fed has been indubitably linked to displays of abnormal behaviour patterns. For instance, crib-biting – an oral stereotypy not recorded in wild horses – was recently studied in young foals (Nicol *et al.*, 2001), and a link was established between the condition of the stomach, specifically the presence of changes in gastric morphology and gastric lesions, of the foals and crib-biting.

8. Nutritional Supplements

Nutritional supplements are readily available to horse owners, both on prescription and from retailers and come in many forms: powders, pastes, drenches, herbs etc. The vast majority are widely used without the recommendation from either a veterinarian or a nutritionist. Nutritional supplements are fed for many reasons, and the benefits they proffer include the following:

- an additional source of vitamins and minerals;
- 'diet enrichment' through providing plants that horses may not have access to;
- ergogenic aids (which claim to enhance performance);
- health benefits (*e.g.* which claim increased immunity, improved hoof appearance, better respiratory function);
- behavioural modification (*e.g.* for 'hormonally challenged' mares or excitable horses).

There are a number of issues that should be taken into account when considering nutritional supplements, but the key ones are: how necessary, how efficacious and how safe is the supplement in question. Some supplements that contain active ingredients have been clinically tested in horses and have proof of efficacy and safety, others may not have been clinically tested in horses and have no published proof of efficacy. There are even supplements being sold that contain ingredients that are known not to be absorbed or efficacious in the horse. There are many supplements available, which claim unsubstantiated benefits, and it would be preferable, if perhaps rather optimistic, that all products should be clinically tested with results published in peer reviewed journals. It is often the case that easy solutions (or so called 'quick fixes') are sought for behavioural problems or lack of training that would be better solved with some time spent working with the animal.

To assist in the question 'to supplement or not?' the following areas should be considered. Firstly, before offering any horse a supplement outwith its normal diet, there are a number of questions that should be asked:

- Is the horse being provided with the optimum balanced diet for their current health and lifestage? Manufacturers of feedstuffs that are intended to provide the concentrate portion of a horse's diet will have the produced a mineral and vitamin level that is designed for a horse in a certain lifestage and/or under a certain workload, i.e they will be in ratio with the calorific content. If the horse does not require the recommended amount of that feed, and it is not possible to change over to a more suitable feedstuff then it may be necessary to supplement the horse's ration with additional minerals and vitamins, in order to supply all its' nutritional requirements.

- Is the horse being provided with the optimum environment – this includes ability to forage and interact with conspecifics. Sub-optimal condition or poor performance or behaviour may be a reflection of an inadequate environment, which may impact both on the horse's physiological and psychological well-being. Supplements may have no impact or may mask the true root of the problem.
- Is the horse capable of fulfilling the task required – *i.e.* is it being provided with the correct training (in saddle and groundwork) and exercise level to fulfill the task required? All athletes need to be properly trained and in peak fitness to perform their best, the horse is no different. Ergogenic aids should be considered only as one of the additional tools available, and should not be used as a replacement for appropriate training. In addition, many performance or behaviour issues can be resolved more permanently with patience, time and a regular modification/training programme, *i.e.* there really is no substitute for time spent working with the animal in question.
- Are there any health issues that require veterinary treatment that may need to be addressed? It may be neither ethical nor safe to use supplements to mask pain in order to get good performance from your horse. One of the purposes of pain can be to restrict movement within the physical bounds in order to minimise the risk of further damage. In addition, pain is often the cause of behavioural problems in horses (Casey 1999) and steps to ensure that the horse is pain-free and that any equipment being used is appropriate should be paramount.

If the nutrition, the environment, the training and the health issues have been addressed, and there is still a perceived requirement for improvement – whether it be performance, condition or behaviour, then supplements may be considered. At this point, the next set of questions should be about defining the problem – is it a general loss of condition or are there specific indicators about what may be most beneficial. For example, the supplements that are offered may differ for poor hoof or coat condition as opposed to a general loss of body condition. In addition, the advice of a nutritionist or a veterinarian with nutritional training will help with the decision making process. If anything is being added to the diet it is important to ensure that the addition to the horse's normal diet does not take any one nutrient over recommended levels in total *e.g.* selenium is often added to the diet of horses but it has been recommended that total daily intakes do not exceed around 1 mg per 100 kg bodyweight. In addition it is necessary consider the response time of the supplement, and the different responses of individuals, since some nutritional supplements are required to be fed for long periods before a noticeable response occurs, *e.g.* it is known that biotin needs to be fed for several months before any improvement to poor hoof quality may be visible in those individuals in which it is effective.

Once the problem has been defined, and the desired action or active ingredients, which are required, have been identified, how do you choose a safe and efficacious supplement? It cannot be taken for granted that all products are either efficacious or safe for horses, so care must be taken. There are supplements which have no proof of efficacy, have never been clinically tested on horses and for which no toxicity data in horses is available (see Poppenga 2001). Many product manufacturers claim that a ingredient 'X' is well known for causing response 'Y', but they fail to mention that all of the data is from human experiments, and although some extrapolations from human data to horses have been well founded, there are many which are not (Harris & Harris 1998). Often more intensive evaluation of supplements on the market can reveal inadequate experimental design and inaccurate assumptions. For example some vitamins and minerals can be toxic at high levels and the active ingredients in some herbs are a drug used by humans *e.g.* salycilic acid (aspirin) obtained from the bark of *Salix alba* (white willow). In this case more may not be better. Finally it is essential before using a supplement that contra-indications are assessed. There have been few satisfactory studies that cover this area, although some side-effects are known. For example it is advised that gingko is not used with aspirin, non steroidal anti-inflammatories or anti-coagulants due to its profound inhibition of platelet-activating factor (Davidson 1999).

9. Conclusions

The horse has evolved to fulfil a specific niche as a social animal, grazing and browsing throughout the day, conscious of, and ready to respond to, its' position as a prey item – and as such, is very successful in this role. The tasks required of today's horse, and the different management practices, including diet, imposed as a consequence of this role, do not always match its' physical or mental needs, and often may be the source of problems that develop either in the horse's well-being or in the relationship between horse and owner. While it is unrealistic to believe all horses will ever be maintained under wholly natural conditions (indeed their status in society could be drastically reduced if that were the case), we should encourage people to alter their management practices, examine their feeding programmes and make changes where possible (Davidson 1999). In summary, the following points should be considered in order to prevent the onset of nutritionally related problems and enhance the welfare of the performance horse:

- Where possible 24 hour access to grazing should be allowed. Grazing quality should be appropriate – many modern pastures are rich monocultures with too little fibre content in the grass, and therefore may need to be supplemented or managed to provide more optimal grazing. Nutritional supplementation, especially vitamins and minerals, may be needed especially for the performance horse, pregnant/lactating mare and the growing animal.
- If stabled, as much of the diet as possible, should be forage, and preferably a selection of different forages should be offered. Recent work (Goodwin *et al.*, 2001) found that at least in the short term, stabled horses showed a preference

for a stable with multiple forages over a stable with the standard single forage. Providing different types of forages to the stabled horse reflects in a small way the more varied diet available to grazing horses.

- Where appropriate to the individual, ad-libitum hay should be provided. Although some horses initially gorge on ad-lib hay, after about 12 days of ad-lib hay, most horses will stabilise to a constant intake.
- If high-energy complementary feeds are required, they should be introduced gradually and fed in small amounts in multiple meals rather than in one large meal. As an alternative to feeding high grain diets, the horse could be maintained on a diet composed of fibre, with additional energy added in the form of oil (remembering to supplement with vitamins and minerals as necessary).
- Feed should be changed very gradually.
- The diet should be nutritionally balanced, either too little or too much of any nutrient (whether it be protein, a vitamin or carbohydrate) compared to the individual horse's particular nutritional requirements, may cause changes in behaviour or clinical problems (such as colic).
- Plants that are poisonous to horses should be identified and horses should not have access to them.
- The horse should live a stress-free life. Stress may come in many guises and may be individual to that horse – travelling, removing stable companions, weaning, or increased intensity in training. Any changes in the management practice of the individual horse and its environment, should be minimised and introduced gradually.

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