Impact of Nutrition and Feeding practices on equines, their behaviour and welfare

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Abstract

In the wild, horses spend most of the day roaming and foraging in an externally variable environment as part of a herd. As non-ruminant herbivores they are well suited to a high fibre, low starch diet. They rarely fast voluntarily for more than 2 –4 hrs at a time and would naturally forage for 16- 18hrs a day. Modern horse management often brings horses into small-enclosed, isolated environments and limits the feeding occasions. What and when they are able to eat, is now predominantly determined by ourselves and we therefore have to take responsibility for the effects that our choice of managemental practices have on their health as well as their behaviour and welfare. Many managemental practices have the potential to be less than optimal for horse welfare. In addition, many people, in developed countries, have horses in order to ride them or to watch them being ridden. Being naturally fear and flight animals, their behaviour becomes increasingly important when being ridden in environments beyond the rider's control or under competitive circumstances. Currently much of the interest around diet and nutrition therefore is focused on the areas of temperament and tractability.

This paper highlights the impact that diet and the way we feed can have, both positively and negatively, on the behaviour and welfare of horses especially the young growing animal. It will concentrate on the work published by WALTHAM and its collaborators since 1995, highlighting the work on feeding practices, feeding behaviour as well as the impact of diet on behaviour.

Key words : Welfare, nutrition, equine, behaviour, management.

Introduction: what is the challenge?

Feeding and stable management practices vary greatly around the world and it is probable that almost any permutation of regimen could be found somewhere. Many factors influence how horses are kept but in general, the way horses are fed and managed primarily reflects the purpose for which they are kept (e.g. native breeding pony vs., the working animal vs racing Thoroughbred) as well as their location (third world vs. developing vs developed : rural vs urban);; their breed/age, local or regional customs, the time of year, availability of feedstuffs etc as well as the owner's financial situation (Harris 1997, Harris 2000). The potential impact of managemental practices on the welfare of the horse depends upon how the horses are being kept in the first instance. In countries where feed is limited the welfare issues tend to be different from more developed countries where problems may be more associated with an excess of feed.

Regardless, it is being increasingly apparent that many managemental practices may not be optimal for the welfare of horses given that the ideal includes daily access to grazing, prolonged foraging time and contact with other horses (Davidson and Harris 2003). BUT, what is the ideal for the modern day horse that enables its needs to be met whilst fulfilling the requirements of its human provider? 24hr pasture turn out perhaps? However, many pastures, for climatic and geographical reasons will not provide, even if well managed, all nutritional requirements throughout the whole year especially for horses that are pregnant, lactating,

growing or exercising. Overgrazing and inadequate endoparasitic control can also be detrimental to the health of horses. If left unmanaged the habit of pattern grazing can lead to the grazed areas being impoverished, bare and potentially infested with unwanted or even poisonous plants such as ragwort (*senico jacobaea*). Pastures established for other herbivores, such as cattle, may not be any better as they tend to be too 'rich' for horses. Certain animals prone to conditions such as obesity, laminitis or tying up require restricted access to pastures especially at certain times of the year. Inadequately fenced and maintained pastures may actually prove to be hazardous. Stabling, on the other hand, does provide many advantages including 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 (Davidson & Harris 2003).

As the above illustrates it is not easy to provide an ideal environment for the horse. However, it is obviously important to try and therefore this review will concentrate on some of the work we have published in the areas of feeding practices, feeding behaviour and the effect of diet on behaviour.

Feeding practices

The challenge today, therefore, is not just to understand when certain practices compromise the welfare of the horses in our care but to be able to make recommendations that allow horses to remain an integral part of many people's working life or leisure time whilst minimising adverse effects on their welfare. Animal welfare has been defined ecologically as the good fit of an animal to its environment (Kronfeld et al 1998). These authors mention that this can be evaluated from the point of view of the animal and its adaptation or alternatively from how the environment can be adapted to the animal, for example, by improved housing, training or *feeding*. Much of our work over the last few years has looked at optimal feeding practices that not only support performance but also support the physiological and psychological requirements of horses, thereby, helping to minimise any health or welfare issues. Feeding practices are important and this paper will review two key aspects – when to feed before exercise and the role of chaff addition.

When and what to feed before exercise

There has been considerable debate across the years about when and what should be fed to horses before they are exercised and/or at a competition in order to reduce the risk of gastrointestinal disturbances and other adverse sequellae. Should they be fed or fasted and when should the hay be fed in relation to the grain and/or exercise?

Initially the effect of feeding either a fat supplemented or a more traditional high carbohydrate meal and exercising 3 or 8 hrs post feeding was evaluated (Pagan et al 1995). The most important factor influencing the glucose response during exercise was the time of feeding not the type of diet with those horses fed the cereal based diet 3hrs before exercise demonstrating large decreases in blood glucose levels during the exercise bout. This was followed by a series of studies investigating the effect of feeding hay with or without grain (Pagan & Harris 1999). The insulin, glucose, FFA and various haematological responses of thoroughbred horses at rest and during a simulated competition exercise test (CET: the cross-country day at a 3DE) were evaluated. Resting horses were either given hay 2hrs before , with or 4 hrs after a grain meal. Feeding hay (~ 2.3kg) before or with a grain meal (~2.3kg) significantly reduced the glycaemic response to the grain, whilst the total protein concentrations and water intake both increased. It was thought that this might be as a result of

an increased rate of passage of grain through the gastrointestinal tract when the hay was present. This could in turn result in reduced digestion of the grain in the small intestine especially if a large grain meal is fed, which could lead potentially to increased levels of starch reaching the hindgut causing disturbances to the microflora. Interestingly the packed cell volume decreased considerably over the first 4hrs following the grain feeding (in those fed the hay 4 hrs after the grain).

The next study evaluated the following diets in exercising horses:

1. *Fast*: overnight fast;
2. *Grain plus ad lib Hay*: ad lib hay the night before and before the CET plus ~2.3kg of a grain based meal 2 hrs prior to the CET;
3. Grain *plus Hay*: ~2.3kg hay 3 hrs before the CET and ~2.3kg feed 2 hrs prior to the CET;
4. *Grain*: ~2.3kg of feed 2 hr prior to the exercise with ~2.3Kg hay at 10pm the night before.

Plasma volume was determined immediately before exercise using an indocyanine green clearance method. Feeding grain reduced the free fatty acid availability and, as before, increased the blood glucose disappearance during exercise. The decrease in glucose during phase A and B of the CET seen in the first study was not attenuated by feeding hay. The fasted horses had fairly stable glucose concentrations during the exercise bout but had lower post exercise glucose and insulin concentrations.

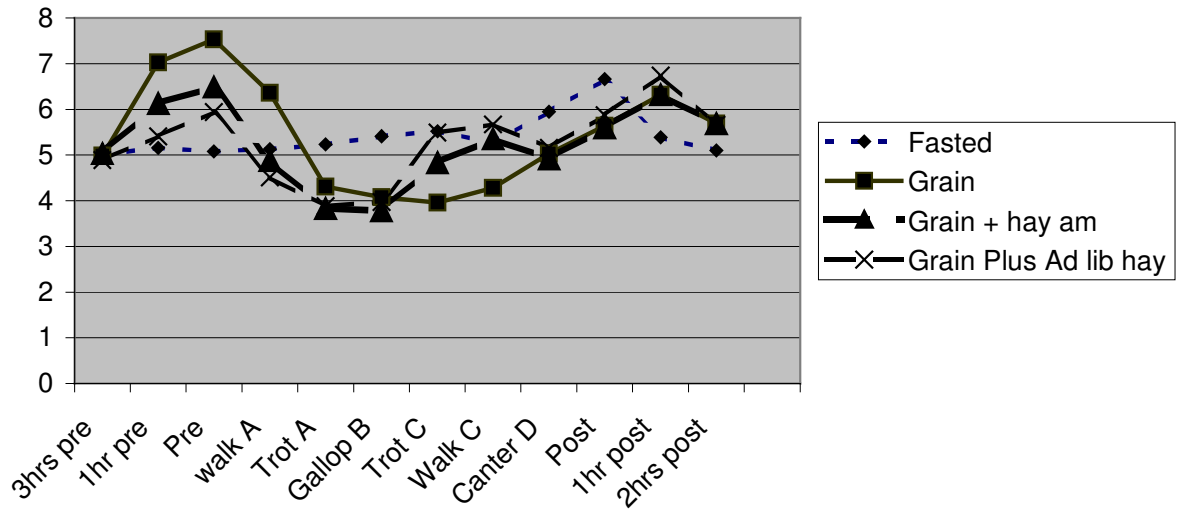

Fig 1 Glucose concentrations (mmol/l) before during and after a simulated competition exercise test.

Feeding hay either alongside the grain or *ad libitum* resulted in reduced plasma volume and higher lactate production as well as higher heart rates during the exercise. Fasted horses had lower blood lactate after the 8-min canter compared to the others. There were also effects of diet on cortisol levels and body weight. However, it should be pointed out that the *ad-lib* hay group had higher bodyweights (as they were not accustomed to such a diet) than the other groups.

The final study in this series evaluated the effects of feeding forage, without any grain, on substrate utilisation and performance during exercise. In this instance the diets were

1. *Fast*: overnight fast*;* Grain and hay was fed during the adaptation phase but not on the day of the CET.
2. *Ad lib hay*: For 7 days before the CET the horses were offered 5- 6kg grass hay at 2200h and 1.13kg at 1200 and ~2.4kg at 1600. If all the hay ad been consumed before the CET they were offered 2kg hay that morning. Grain was fed during the adaptation phase but not on the day of the CET.
3. *Am hay* : ~2.3kg hay 2200hrs on the day before and ~2.3kg 3 hrs before the CET . Grain was fed during the adaptation phase but not on the day of the CET.
4. Grazing : for 7 nights before the CET they were housed in small grass paddocks overnight and then kept in stalls and offered grain and hay. On the morning of the CET the horses were removed from the paddocks at 0600 and no hay was given.

There was relatively little effect of these different feeding practices on the glucose response although it tended to be lower in the Am hay group for most of the exercise see fig 2

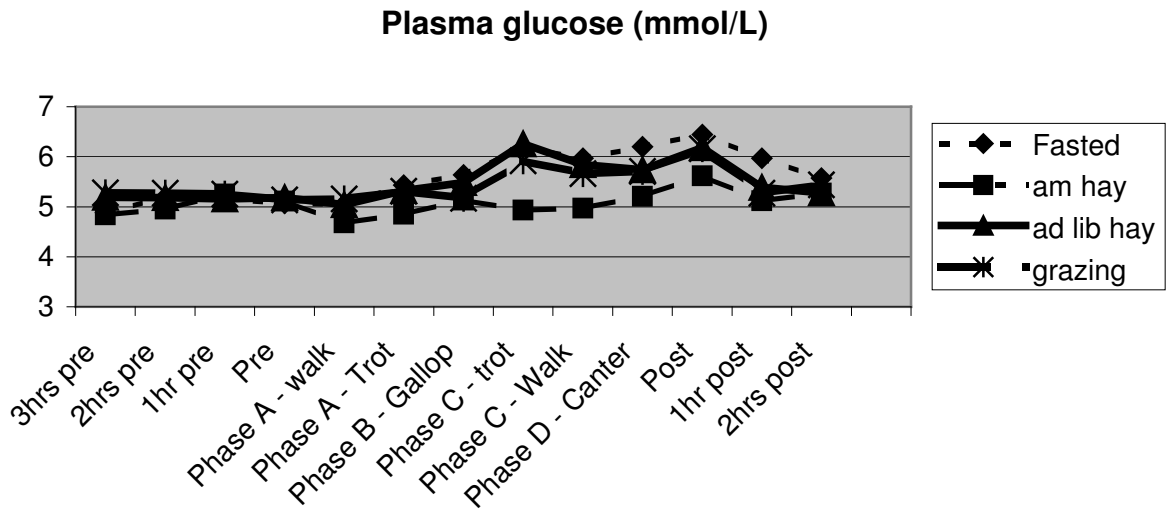

Fig 2 Plasma glucose concentrations (mmol/l) before during and after a simultated competition exercise test.

Hay feeding did not affect FFA nor cortisol levels. In this study there was no significant effect of the ad lib hay on total protein concentrations perhaps because they had adjusted to the adlib feeding regimen. Feeding forage before exercise therefore did not appear to adversely affect performance (other than the potential to increase body weight and possibly reduce plasma volume if the intake is not controlled). The horses that had been grazing before the CET tended to be heavier but did not show the same apparent changes in plasma volume or heart rate as they did with the hay feeding perhaps, because they were better able to equilibrate fluid between the gut and the plasma.

In a study looking at more intensive exercise (2 mins at 15% VO_{2max}) the effect of restricted hay intake (for 3 days at 1% BW ~ 4.5kg hay) compared to *ad libitum* feeding (~10kg hay) was evaluated (Rice et al 2001). Feed and water were removed 4hrs before the exercise. The restricted hay intake resulted in a decrease of approximately 2% in BW (528 vs 539kg), which was associated with an increase in the mass specific rate of oxygen consumption during sprint exercise (243 Vs 233ml/kg/2min) with a corresponding decrease in anaerobic energy expenditure. Peak lactate was higher in the adlib fed horses (22.2 Vs 19.1 mM). This suggested that it might be beneficial to reduce hay intake to the recommended

minimum of 1%Bwt/day. However, as very few horses in intense performance work are currently fed *ad-lib* forage, further work is needed to determine the exact nature and level of optimal amount for horses in intensive work.

Conclusions

These studies confirm that insulin is a potent inhibitor of lipolysis and fatty acid oxidation in skeletal muscle, and also promotes glucose uptake into muscle (via recruitment of the transporter protein GLUT4 to the sarcolemma). Thus, hyperinsulinemia at exercise onset will tend to suppress non-esterified fatty acid (NEFA) availability plus lipid oxidation and increase reliance on carbohydrate stores (including plasma glucose) for energy production. This decrease in plasma glucose concentration may be short-lived so that during prolonged moderate-intensity exercise (e.g. 60 min at 50% of VO_{2max}), the plasma glucose concentrations of grain fed horses are not substantially different from horses fasted before exercise. On the other hand, plasma NEFA and lipid oxidation remain lower when compared to the fasted state throughout exercise (Jose-Cunilleras *et al.* 2002). It is therefore currently recommended for that for horses competing in endurance, eventing and show jumping they should not be given cereal based meals within 2 – 3hrs of the competition. Large meals (hay or grain or a combination) consumed near the start of exercise may result in a decrease in plasma volume as a result of fluid shifts into the gastrointestinal tract. Such reductions in plasma volume could compromise cardiovascular and thermoregulatory function during exercise. This could have led people to recommend total feed restriction prior to competition, which would be contrary to the welfare of these competition horses as total feed restriction increases the risk of gastric ulceration. Fortunately as suggested above small forage meals consumed 2 to 3 hours before exercise may have minimal effect on substrate availability and oxidation during sustained exercise. It is commonly now recommended that horses are allowed to nibble on small forage meals (1-2 kg, as fed) in the 1-3 h period pre-endurance/3DE/show jumping.

This series of studies therefore highlights the role that research can play in defining feeding recommendations that both support performance and the welfare of the competition horse.

Effect of adding chaff

It is not always possible to work horses, especially during training, 3hrs after a small meal. However, especially in quick or greedy eaters eating a concentrate-based meal can result in a significant decrease in plasma volume. Adult horses, around 500kg BW, may secrete more than 100L of fluid per day into the pre-caecal section of the gastrointestinal tract i.e. around 70-100ml/minute (Harris et al 2006). When large meals of either pellets or cereal grains are fed infrequently a transient state of hypovolaemia occurs as a result of meal stimulated upper gastrointestinal secretions. Within one hour of feeding ponies there has been shown to be on average a 15% loss in plasma volume. In quick or greedy feeders this can be up to a 24% loss (Clarke et al 1990). Slow feeders compensate whilst they eat and the resultant volume losses are therefore small. These changes in plasma volume are not seen when frequent small meals are fed.

Slowing down quick and greedy feeders can obviously be advantageous. There are a number of possible ways to do this. In particular we have been evaluating the role of including supplemental chaff at an appropriate chop length. In one study in Australia, the effects of including chaff at the time of feeding, were evaluated in six thoroughbred geldings fed a meal of oats (3 g/kg bodyweight) each morning (Campbell et al 2005). Longer or shorter ground lucerne chaff (4 cm and <2 cm, respectively) was included with this meal at five

inclusion rates ranging from 7% to 37.5% of the total mixed ration. As the amount of chaff was increased the rate of feed intake declined with maximal effect when chaff made up 33% of the ration. The rate of food intake was unaffected by chaff length. This was also found in another series of investigations carried out in Australia. This time they evaluated the effect of including short (<2 cm) lucerne chaff with either a sweet concentrate mix (cereals, pellets, coating: Harris et al 2005a) or an oat meal fed at 300g/100kg BW (Harris et al 2005b) at 6% and 26% of the total fed ration (6 and 35% addition on top of the core rations). The rate of intake (over 3 consecutive days) as well as the glycaemic response to a 2kg meal of hay was initially determined in 8 light-horse geldings before the oats or sweet feed was fed. The rate of feed intake was slowest during the period that hay was fed in both studies (31g/min). The sweet feed and oats were ingested at about twice the rate of hay (77 and 58g/min respectively). The addition of 6% chaff to the concentrate mix did not alter the rate of intake, but an apparent decrease in the rate of intake was seen with the 26% chaff (49 and 52g/min for the sweet feed and oats respectively) although this was not statistically significant. This was due in part to an increased volume of intake per minute, particularly with the oat meal see fig 3. Under certain circumstances this increase in the intake volume, if associated with reduced chewing, could increase the risk of complications such as choke.

There was no correlation between the area under the curve (AUC) for blood glucose concentrations and rate of feed intake and. The AUC and peak blood glucose level was significantly higher for the sweet feed compared with hay, and there was no significant effect of chaff inclusion on these parameters for either the oats or the sweet feed. This suggests that there is no significant adverse effect on starch digestion in the small intestine of such chaff addition.

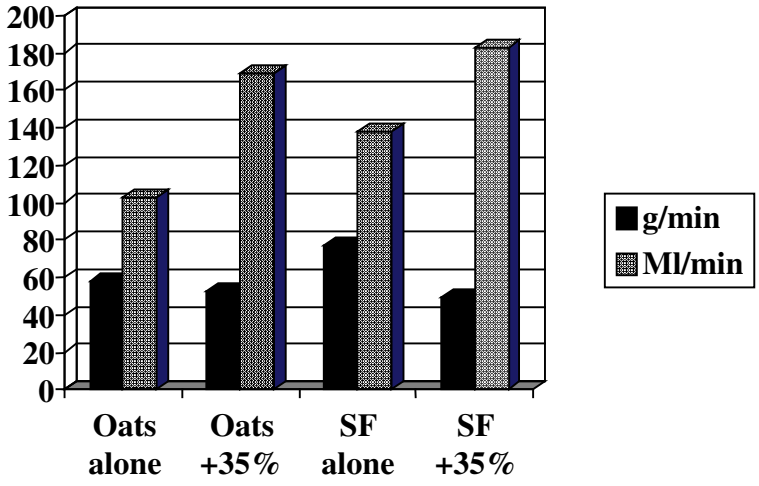

Fig 3 Amount (g/min) and volume (ml/min) of oats and sweet feed fed alone or with a 35% addition of chaff.

Another study looked at the effect of including 10%, 20% or 30% of straw chopped into either 2.5cm or 4cm lengths to a trial pellet fibre mix (containing 10% short cropped lucerne: Ellis et al 2005) also showed no effect of chaff length. Around 1 kg of the mix was fed to horses each morning and evening and the time taken for horses to eat the various feeds as well as the average number of chews per minute were monitored . The rate of chewing remained about the same regardless of the type of food fed. However, the type of food had a significant effect on the rate of intake and the total number of chews per kg. Diets containing added straw were eaten much more slowly than their normal diet mix, (containing 50% pellets, 15% lucerne-straw chaff, and 35% soaked sugar beet pulp), their normal pellets and

the trial pellets on their own. There was, however, no significant effect of adding 10% straw chaff to the trial pellets with 10% choped alfalfa but there was a significant effect of the 20% and 30% addition. Whilst adding more than 20% of the straw chaff had no significant effect the intake rate did decrease and the time taken to eat the meal increased. Average food intake times ranged from 7 min/kg on the normal diet to 16 min/kg when the longer chaff was included at 30% to the pellet/chaff mix.

Conclusion

These studies suggest that including chaff at levels of around 25 – 30% inclusion rate can lead to horses spending more time eating their meal which, in turn, is likely to lead to increased saliva production and potentially improved buffering of the gastric contents (Harris et al 2006). These studies did not show the same apparent adverse effect on glycaemic response that was seen with the larger amounts of hay (Pagan & Harris 1999). Again this work has led to the recommendations of a feeding practice that is of benefit of the horse but does not appear to adversely affect performance. Further work is needed, however, to evaluate optimal lengths and types of chaff.

Feed intake behaviour

Interestingly while there have perhaps been great advances in the last 15years in our understanding of the dietary requirements of horses, as well as the functionality of nutrients, the way in which horses eat and are fed in domestic environments has attracted comparatively little research interest. For humans and domestic pets, eating involves more than simply the ingestion of food. It encompasses facets such as sensory stimulation and social interaction. Proper selection and mastication off food is also essential for the maintenance of digestive health.

Side Preferences

In nutritional studies, food preferences are often determined by measuring the relative intakes of two food choices positioned beside another. One possible source of error in such studies is the consistent selection of one food based on its position, i.e. left or right, alone. This is termed side preference feeding and was investigated by recording food intake and feeding behaviours when the same feed as was offered to horses in two separate containers (Bottom et al 2005) Eight of the 18 horses in the study (44%) demonstrated the development of significant side preferences over time, with an equal number of horse showing preferences for food positioned on the left or right. Interestingly, when the horses were divided into age groups, the incidence of side preference was higher in older (16-22 years of age) horses than younger (2-4 years) and middle aged (8-14 years) horses. The strength of the side preference was also greater in the older horses. The time that horses spent eating also increased with age, whereas the young horses tended to spend more time exploring the feed and the environment rather than ingesting food see Table 1

Table 1 – Percentage of time spent in locomotory or non-ingestive behaviour during a meal

	Non-ingestive (%)	**Locomotory (%)**
Young	**28.4**	**7.6**
Middle	**4.7**	**0.5**
Old	**0.1**	**0.0**

Reduction in exploratory behaviour with age may explain the observed rise in the incidence and strength of side preferences, since these horses rapidly and exclusively choose to consume one of the feed offerings. These findings have important implications for the design and interpretation of two-choice preference tests, particularly when they are used in middle and old age horses.

Flavour Choice

Like most grazing herbivores, horses are thought to select their food according to its sensory properties and specifically visual cues, odour, taste, texture, availability and variety. There is, however, little published information on the role of flavour in food selection by domestic horses. To address this, the effects of flavour and concentrate formulation on food selection and acceptance were investigated in a series of trials. The acceptance/rejection and quantity and rate of consumption of cereal by-product meals containing 15 separate flavours was assessed. Twelve flavours were universally accepted by the eight horses tested, demonstrating that horses are attracted to a wide range of flavours (Goodwin et al 2005a). The eight most readily consumed were subsequently presented in paired preference tests. From these tests, the flavours were ranked in descending order of preference as fenugreek, banana, cherry, rosemary, cumin, carrot, peppermint and oregano. In the final part of this study, the consumption of mineral pellets flavoured with fenugreek or banana was found to be greater than that of unflavoured pellets (66 vs 52 vs unflavoured mean intake time(s) for fenugreek vs banana vs unflavoured). There was no difference between the fenugeek and banana flavoured pellets. These findings demonstrate that, in the short-term at least, flavour does have a significant impact on diet selection, acceptance and consumption and may help to ensure that horse ingest certain feedstuffs that some may try and avoid.

The effects of sensory variety on the selection and ingestive behaviour of horses was also investigated in a separate set of trials (Goodwin et al 2005b), which looked at the influences of concentrate formulation, physical composition and flavour. The flavours assessed were molasses, mint, herbs and garlic. All of the flavoured concentrates were well accepted by the eight horses in the study but significant changes in concentrate preference were observed between and within trials. It was observed that horses repeatedly interrupted the consumption of a concentrate, for which they had previously demonstrated a preference, to forage on other diets that were presented in 'multiple taste tests'. This meant that their consumption of the preferred concentrate was always lower in multiple compared with single test sessions. The total time spent foraging was, however, higher in these multiple sessions. The basis for switches in preference is likely to reflect an evolutionary adaptation that allows horses to explore and exploit the heterogeneity of dietary resources available. This would allow them to choose a diet of better quality than the average vegetation on offer. These trials showed that manipulating a single sensory characteristic of a diet is sufficient to affect both foraging and non-foraging behaviours, for example horses stood inactive for longer periods when only a single concentrate was available.

Environmental enrichment

Concentrate feeds are usually offered to horses in buckets or mangers and this means of presentation does nothing to slow the rate at which these foods are consumed. Several so-called foraging devices are available commercially and can be used to provide part of the ration in a less easily accessible manner and provide sensory stimulation. Some of these operant foraging devices are based on the Edinburgh foodball (Winskill, et al., 1996) which

aim to prolong food-handling time and are designed to be presented on the floor. The ration is placed inside these devices, which and horses must either nuzzle the unit or move it their head or a foot to release food. The one major drawback to these current devices is the fact that they are placed on the floor, raising concerns about the ingestion of foreign materials with the food. An alternative is to use foraging devices that fit inside feed mangers or buckets and the behavioural benefits of these were therefore evaluated (Goodwin et al 2006). Horses were presented with three devices varying in sensory complexity – round, square and polyhedral in design – in either a manger or bucket and their behaviour recorded. All horses foraged successfully from at least one of the devices but also exhibited some frustration, either biting or pawing at the devices, and frequently removed the devices from the buckets. This was not the case when the devices were placed in feed mangers. The polyhedral design appeared the most promising in that it was consistently and repeatedly associated with the longest duration of foraging. However the study did suggest that when the dispensing of pellets, as a means of enriching the environment occurs in an unpredictable way, the unpredictability of reward could be a source of frustration.

Benefits of a varied diet

Horses tend not to eat a discrete meal from one plant nor do they concentrate solely upon one species of plant even if it is a preferred plant species (Mariner 1980). Horses appear to have evolved by consuming a varied and *ad libitum* roughage diet typically high in fibre and this contrasts with the restricted forage diet that most stabled horses are fed. The feeding behaviour of free ranging horses may be more complex than those kept in stables (Carson & Wood-Gush 1983) as the diet of free ranging horses tends to be very varied on a daily basis and from season to season (Gill 1988, Hansen 1976). Previous studies have linked this to changes in patterns of behaviour, including a tendency for horses to eat their straw bed, a habit that can lead to colic.

In order to start to investigate this the behaviour of 12 competition horses was monitored during a number of trials where they were either provided with a single food or six types of feed (Goodwin et al 2002). The work showed that, at least in the short term, by supplying multiple 'forages' it was possible to significantly affect the behaviour of the stabled horses (promoting more natural foraging behaviour patterns) whilst reducing the consumption of straw as well as the amount of non- foraging behaviours such as 'weaving' and 'pawing'. This has been followed up by more long term studies in 9 horses, aged 5-20 years and of mixed breeding, which were fed either a single forage (hay) or multiple forages (three short-chop and three long-chop commercially available forages) in two daily feeds for 9 days, and then fed the alternate ration (Thorne et al 2005). The short forages were presented in individual buckets, whereas the long forages were provided in separate hay nets. The horses were observed on days 3, 5, 7 and 9 of each period for the 25 minutes following forage delivery in the morning and afternoon. This study showed that when fed the multiple forages, horses performed foraging behaviour significantly more frequently and for longer periods than when fed the single forage. Foraging on the six sources offered differed in frequency, latency and duration, and, while clear preferences were demonstrated, all forages were sampled during the periods of observation. Horses on the single forage spent significantly longer periods performing behaviours thought to represent a search for alternative food sources, such as moving and looking out of the stable. This type of enrichment may offer horse owners a practical and easily adopted means of facilitating foraging behaviour in their horses, and may help prevent the occurrence of stereotypical and redirected behaviours.

Is the presence of another horsed beneficial or stressful during feeding?

Increasing visual contact between horses in a stable setting is often anecdotally assumed to be beneficial to the well being of horses. There has, however, been limited research into the relationship between neighbouring horses, especially at potentially stressful periods such as feeding. Whether the presence of a familiar horse during meal times is of benefit or not was therefore investigated in Scotland (Redgate et al 2004a). Six horses were fed alone in their own stable and then in a familiar arena in the presence of another horse that was eating or not eating. The horses were fed a standard plain concentrate feed and behaviour was recorded every 5 seconds for a 5-minute period. There were individual differences in the amount of vigilant behaviour recorded, which was expressed as 'eat hover' (head hovering over the bucket whilst chewing, head below the withers) and 'eat head up' (chewing with head above withers). These feeding behaviours were thought to allow the horse to survey the environment. Some horses showed more vigilant behaviour in the presence of another horse than when stabled alone, and this was regardless of whether the other horse was eating or not. Conversely other horses showed more vigilant behaviour when fed in the stable alone. Further work is required to establish if this effect is seen with larger groups of horses and to identify stable designs that best cater for individual, social and behavioural needs.

No of meals

Another potential method for enriching the stable environment and reducing stereotypic behaviours is to provide more frequent, but smaller, concentrate meals. This was evaluated by splitting the daily concentrate ration into two, four or six equal feeds (Cooper et al 2005). Prior to the study, baseline behavioural characteristics were recorded and, while these showed a low incidence of stereotypic behaviours, it was clear that such behaviour was more commonly seen in the afternoon which coincided with there being less forage available. The incidence of oral stereoptypies – defined as repetitive oral activity without ingestive intention, such as sham chewing, tongue rolling, and biting, chewing and licking of stable fittings - decreased as the number of meals increased. There was, however, a concomitant increase in anticipatory-related activities like weaving and nodding prior to feeding. The incidence of weaving, nodding and oral stereotypic behaviours also increased in the control horses that continued to be fed twice a day.

As suggested by these authors increasing mealtimes may lead to an increase in post-feeding stereotypy, unless for example the individual meal-sizes are large enough to be nutritionally satisfactory without being so large as to cause digestive dysfunction or the horses have access to an alternative more acceptable means of expressing feeding behaviour such as access to forage (Goodwin et al 2002).

Conclusions

These studies suggest for example that providing sensory variety may present a means of increasing dietary variety without drastically changing the nutrient content of the ration, and this is likely to be of particular benefit for horses fed restricted or monotonous diets. There also appear to be behavioural advantages from providing multiple forages to stabled horses by enriching their environment by offering variety and enabling the expression of foraging behaviours that more closely mimic the patch foraging seen in free-roaming horses.
These results also indicate that the individual nature of horses needs to be considered when determining their optimal management. There are, for example, differences between horses in

respect of their comfort in the presence of another horse during meal times, with some finding it apparently less stressful and others more stressful than being fed alone.

Finally these studies highlight the complexities of trying to modify equine behaviour in a yard situation, where there are multiple stables and interactions between neighbouring and distant horses. While increasing meal frequency did reduce the incidence of some stereotypies, it actually increased these behaviours in horses that were in visual contact and not fed at the same time

Diet and Behaviour

There continues to be considerable interest in the possible links between diet and behaviour in humans and various animal species. Horses have not escaped this attention since the process of domestication has necessitated changes in their freedom and diet that potentially impact upon their behaviour. For instance, the development of stereotypic behaviours like weaving and crib-biting in stabled horses has been linked with certain feeding practices, most notably high concentrate and/or low forage diets (McGreevy et al 1995, Waters et al 2002). Many people, in developed countries, have horses in order to ride them or to watch them being ridden. Being naturally fear and flight animals, their behaviour becomes increasingly important when being ridden in environments beyond the rider's control – as is often the case!

Currently much of the interest around diet and nutrition is focused on the areas of temperament and tractability. In the late 1990's we reviewed a number of studies that we had been carrying out in this area in America with Colleagues in Virginia (Kronfeld et al 1999). One of these studies looked at spontaneous locomotion as measured by pedometers and also evaluated the 'startle response' to an unusual object (abruptly opening umbrella). The study showed that the replacement of cereals with oil and fibre might diminish spontaneous locomotion and reactivity. Other work confirmed objectively that horses can show differences in behaviour when fed cereal based diet compared with high forage diets (Davidson et al 1998). It has also been shown that the addition of oil to the diet may have a beneficial effect on behaviour (Holland et al 1996) . However the precise mechanism for these dietary effects on behaviour have not been elucidated to date. The paper goes on to describe some of our more recent work in this area.

Diet and the stress of Weaning

One of the most stressful times in a horse's life is thought to be weaning. Back in 1996 studies that compared the effects of diet and weaning method on the stress responses in thoroughbred foals raised on pasture were published (Holland et al 1996). The work confirmed that foals weaned abruptly appeared to be more stressed than those weaned more gradually. However, perhaps more interesting were the findings that the cortisol levels were higher in foals fed a more traditional starch and sugar based diet than those fed the alternative fat and fibre rich concentrate. This was reflected in the foals fed fat and fibre, which appeared to be less, stressed suggesting that diet may affect a foal's ability to handle the stress of weaning.

A later study compared the effects of diet and the use of probiotics on weaning stress (Swanson et al 2003). Dietary supplements, including probiotics, are often given to horses to help maintain digestive function and to help reduce other stressors, such as travelling, and might therefore be beneficial during weaning. In this study half the foals were fed a

commercial probiotic (Probios®) containing lactic acid producing bacteria and the remainder received a placebo from 4 days prior to weaning. Plasma and faecal samples were collected from 4 days prior to, and for 4 days after, weaning and the behaviour of the foals was analysed for measures of stress. The degree of stress experienced by the foals was also assessed by an adrenocorticotrophin hormone response tests conducted 48 hours after weaning. The foals fed the fat and fibre concentrate were found to have significantly higher plasma concentrations of IgA, IgG and α-tocopherol, and had higher faecal pH than those fed the sugar/starch supplement (Fig4).

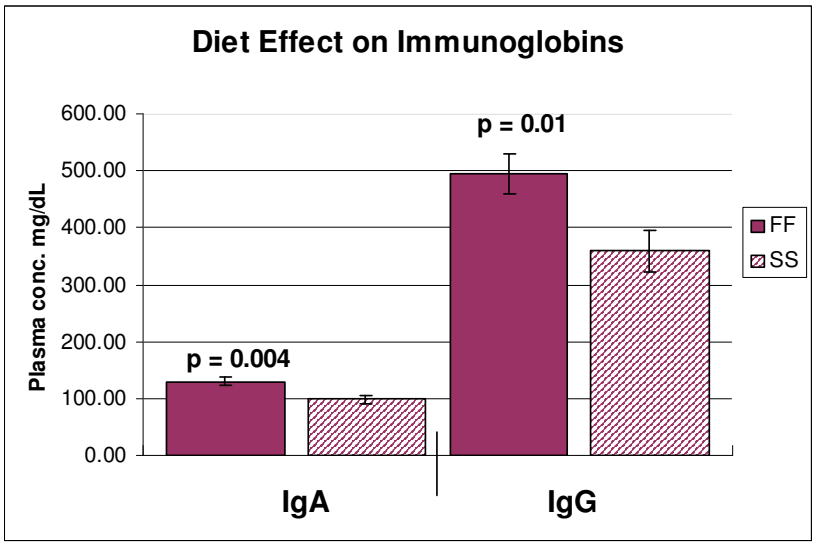

Fig 4 Effect of feeding a supplement rich in Fat and Fibre (solid red) or Starch and sugar (red lines) on plasma immunoglobulin concentrations around weaning.

Foals that received the probiotic had higher faecal lactate and lower faecal acetate concentrations, suggesting that the lactic acid bacteria had survived transit to the hindgut and established colonies there. There was not, however, any effect of the probiotic on plasma markers of immune status or faecal measures of bacterial activity, and no effect of either diet or probiotic on measures of stress. These results indicate that supplementation with a concentrate rich in fat and fibre may improve immune status and encourage a more diverse microbial population in the hindgut, thus ensuring better adaptation to the post-weaning diet, perhaps helping foals to better withstand the physiological stress of weaning.

Another study (Ordakowsk et al 2003) looked primarily at foal feed intake behaviour but it was noted that foals with access to the fat and fibre pasture supplement (FFS) appeared to be more confident in their environment than those fed the starch and sugar rich variant (SSS). The behavioural aspects were explored in more detail in a later publication (Redgate et al 2004b) where it was confirmed that eight out of the ten FFS weanlings appeared to be more relaxed in the test environment in contrast to four out of the ten for the SSS weanlings (Fishers Exact Test, p=0.08 (Figure 5), based on locomotory patterns, interaction with the food provided and vocalization.

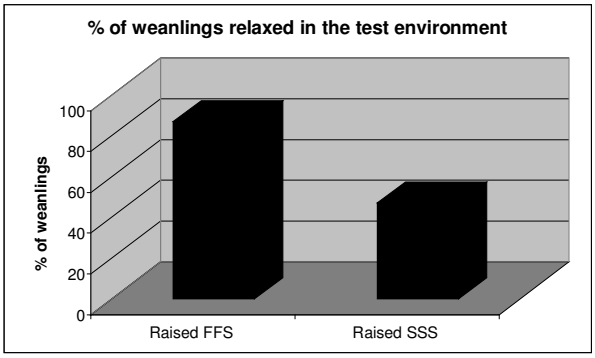

Fig 5 Percentage of weanlings that were relaxed in the text environment fed on starch and sugar rich supplement (SS) or fat and fibre rich supplement (FF)

These observations were explored in more detail in the second study, where behaviour was observed in 17 foals from the age of 2 to 40 weeks. Each foal received either a starch and sugar (SS) diet or a fat and fibre (FF) diet. The two diets contained similar digestible energy, crude protein and micronutrients, but differed in the fat and non-structural carbohydrate balance every 2 weeks from 2 to 40 weeks of age (Nicol et al 2005). Approximately 2 months after weaning, the temperament and tractability of the young horses were assessed using standardised tests. Responses to a novel object, to a novel person, and during a handling test were determined. Foals grew well on both diets and there was no effects of diet on behaviour prior to weaning. Immediately after weaning, foals receiving the fat and fibre supplement cantered less frequently, for a shorter duration, and appeared to be more settled than those fed the starch and sugar supplement. The fat and fibre foals also spent significantly more time investigating and less time looking at a novel object, spent less time walking away from a novel person and completed a handling test in a quicker time.

Overall, the authors concluded that 'the horses that received the FF diet appeared less distressed immediately after weaning and seemed calmer and more inquisitive during a range of temperament tests'.

Conclusions

These studies are thought to be the first research to objectively show that diet can influence behaviour, reactivity and stress responses in normal horses.

DIET AND ABNORMAL BEHAVIOUR

Certain specific behaviour patterns, once thought to be due to boredom or naughtiness, may in fact be linked to modern management practices, and specifically diet in many cases (although stable confinement is also a major factor). Stereotypies have been described as invariant and repetitive behaviour patterns that seemingly have no function and are fairly commonly seen in the domesticated horse. In a 4 year prospective study of young thoroughbred and part thoroughbred horses stereotypic and redirected behaviours affected ~35% of the animals studied (Waters et al 2002). Weaning by confinement was associated with an increased rate of development compared with paddock weaning and housing in barns rather than at grass after weaning resulted in a further increase. Crib-biting was initiated by 10.5% of horses with

a median age of 20 weeks and feeding concentrates after weaning resulted in a 4 fold increase in the rate of development of crib-biting (Waters et al 2002). Crib-biting is a common stereotypic behaviour performed by approximately 5% of adult stabled domestic horses (McGreevy et al., 1995; Redbo et al., 1998; Nicol, 1989) although interestingly it has not been recorded in wild equids. Although the cause(s) of crib-biting are not known, risk factors recently identified include the feeding of high concentrate and, or, low forage diets as well as stable design etc., (McGreevy et al., 1995; Waters et al. 2002). Horses only produce saliva when they chew and recent work investigated the hypothesis that young horses that start to crib bite have gastric mucosa abnormalities (Nicol et al 2002). It was postulated that crib biting provided some relief by helping to produce alkaline saliva which would in turn help buffer the stomach pH especially when other opportunities for mastication were limited. The aim of this work was therefore to evaluate the link between the condition of the stomach and the incidence of cribbing in young foals before the condition becomes well established (when the initiating cause may no longer be present).

Nineteen young horses (weanlings) were observed that had recently started to perform crib-biting, together with 16 non-stereotypic similarly aged horses. The project included the gastroscopic examination of 15 crib-biting and nine normal foals, who were then randomly assigned to either a control or antacid diet (the same base complementary ration with the addition of Neighlox: KPL Technology Inc.) for 3 months and the stomachs re-examined. Behaviour was monitored by direct observation at various points throughout the 3-month period. At the start of the study : within the crib-biting foals 20% (3) had ulcers only, 13% (2) had inflammation only, 27% (4) had both ulcers and inflammation, and 40% (6) had no sign of ulcers or inflammation. Of the normal foals, 11% (1) had ulcers only, none had inflammation only, 11% (1) had both ulcers and inflammation, and 78% (7) had no sign of ulcers or inflammation. The ulcers were few in number and generally mild with the exception of 3 of the crib-biting foals that had moderate, heavy or severe ulceration. Crib-biting foals with ulcers at the start of the trial had been performing stereotypic behaviour for a mean of 83 days, whilst foals without ulcers at the start of the trial had been performing stereotypic behaviour for a mean of 114 days. Overall at the first gastroscopy, the stomachs of crib-biting foals were found to be significantly more inflamed and ulcerated than those of the normal foals. There is, however, likely to be a continuum in stomach condition from normal foals, through mild crib-biters to more severe crib-biters. The antacid diet resulted in a significant improvement in stomach condition overall ($p<0.05$) – although in those with marked ulceration total resolution did not occur. Crib- biting behaviour declined in most foals, regardless of diet but tended to show a greater decline in foals on the antacid diet ($P<0.1$) especially where there had been an improvement in stomach condition. Foals that showed the greatest reduction in ulceration score also tended to show the greatest reductions in crib-biting frequency and duration.

In an additional pilot study the authors placed six foals on a specific weanling diet (EP patent granted) where the energy came predominantly from fat and fibre rather than from more traditional sugar and starch sources. This diet was designed in part to increase the time spent chewing and two foals on this diet stopped crib-biting after 3 months and one foal significantly reduced the incidence of crib-biting.

Conclusions

These novel results suggested an association between stomach condition and abnormal behaviour that can be modulated through diet. These results add weight to the belief that crib-

biting is initiated in foals in response to more acid stomach conditions, or to increased sensitivity to normal levels of acidity. Altering gastric acidity should, therefore, modify the expression of this behaviour and this was supported by the changes in gastric ulceration observed.

Summary

The above provides a brief insight into some of the work that has recently been undertaken to explore the influence that the way we feed and manage our horses can have on their behaviour, welfare and performance. The end result may not only reflect the practices used but also the individual horse's response to such practices. This individuality is an important consideration when we look at means to improve the way that we manage and keep the animals in our care.

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