

THE EFFECTS OF NUTRITIONAL MANAGEMENT ON BEHAVIOUR IN THOROUGHBRED RACEHORSES

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DECLARATION

I declare that this dissertation is my own work, except for assistance that is acknowledged or where due reference is made in the text. The results contained in this dissertation have not been submitted, in whole or in part, for a degree at another University.



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Marion Young

Supervisor

"There are no problem horses, only problem owners"

(Hartley Edwards)

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LIST OF ABBREVIATIONS

AOAC	Association of Official Analytical Chemists
ATP	Adenosine tri-phosphate
AA	Amino acids
ADF	Acid detergent fibre
BW	Body weight in kg
CF	Crude fibre
cm	Centimetre
Conc	Concentrate
CP	Crude protein
DC	Digestion coefficient (Apparent)
DE	Digestible energy
DM	Dry matter
GE	Gross energy
GIT	Gastro-intestinal tract
GP	Gas production
kg	Kilogram
kJ	Kilojoules
kPa	Kilopascals
LED	Light emitting electrode
MCal	Megacalories
MJ	Megajoules
ml	Millilitres
ME	Metabolizable energy
N	Nitrogen
NDF	Neutral detergent fibre
NE	Net energy
NRC	National Research Council
SASI	Statistical Analysis Systems Institute
TDN	Total digestible nutrients
VFA	Volatile fatty acid
Wt	Weight

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ABSTRACT

This dissertation is the product of two behaviour studies and an *in vitro* fermentation trial. Both behaviour studies were conducted at the Ashburton Racehorse-Training Centre in Ashburton, near Pietermaritzburg in KwaZulu- Natal.

The first behaviour study evaluated differences in behaviours obtained through feeding either twice or four times daily. This trial showed ($P<0.001$) that horses fed twice a day spend a greater proportion of their day in stereotypic or vice-like behaviours. Horses eating four times a day ate less hay ($P<0.001$) and more concentrate ($P<0.05$) than horses being fed twice a day. Horses in both yards ate more hay ($P<0.05$) when exercise intensity was increased. Defecation frequency was higher on days when exercise intensity was high ($P<0.05$) and in the yard where horses were fed four times per day ($P<0.01$). Faecal weight was greater ($P<0.05$), horses lay down more frequently ($P<0.05$), spent more time eating concentrate ($P<0.001$) and less time eating hay ($P<0.001$) when horses were fed four times per day. Fillies spent more time ($P<0.05$) eating hay than geldings.

The second behaviour study was conducted within one yard only and considered the effects of changes in management strategies on the incidence of stereotypic behaviour. The results did not indicate that changes in management related to exercise intensity would have an effect on behaviours exhibited. However this trial did demonstrate that a reduction in feed intake on days when exercise is reduced will reduce the incidence of stereotypic behaviours. Horses reduced the time spent eating hay when exercise was reduced except that when feeding frequency was reduced in conjunction with reduced exercise, more time was then spent eating hay ($P<0.001$). It was found that fillies spent more time licking surfaces ($P<0.001$) and weaving ($P<0.01$) than geldings, which were more aggressive ($P<0.001$) and ate more bedding ($P<0.05$) than the fillies. All the horses were more alert ($P<0.001$) on days of moderate exercise except when feed was reduced in conjunction with reduced exercise, so that horses were less alert ($P<0.001$) and more time resting ($P<0.001$).

The *in vitro* study was conducted at the department of Animal and Poultry Science at the University of KwaZulu-Natal, Pietermaritzburg. This was a dilution trial, using different ratios of maize and *Eragrostis curvula*. It was shown that as the proportion of maize in the ration was increased so the digestibility and the degradability of the ration increased ($P<0.001$). It was also shown that the adapted two stage digestion techniques described by Tilley & Terry (1963) had lower supernatant pH levels than the samples that underwent microbial digestion only. This was accounted for by a problem with the methodology. The trial had hoped to show a dramatic decrease in pH and increased rates of gas production when the maize portion of the sample was increased.

From the results established during this trial it is clear that application exists in the adoption of this method in *in vitro* feed analysis in the horse industry.

The behaviour studies significantly linked the incidence of stereotypic behaviour to feeding and nutritional management in racehorses. Some explanations of the noted behaviours can be elucidated through the development of *in vitro* protocols, where hindgut pH, degradability and fermentation of different ration mixtures elicit responses in physical terms.

CHAPTER ONE

1 INTRODUCTION

For a horse to reach its full athletic potential requires correct training, management and feeding. The fact that speed records on the race track have changed very little over the past 80-years while production levels for cattle and poultry have increased over 100% in the same time span, shows that horses have been victims of 'fads, foibles and trade secrets' (Ensminger, 1971).

The physiological changes initiated within the horse through feeding will depend on the size, frequency and nutritional balance of a given ration. Physiological changes within the horse will affect the horse's ability to perform and sustain performance. The economical value associated with the performance of these animals is high and warrants research into issues that could ultimately be producing more winners or losers on the racetrack. Performance in the equine athlete is closely associated with the welfare of the horse itself. The natural feeding habit of the horse is to consume small amounts of feed often i.e. trickle feed (Kohnke, 1998). However, for practical management purposes, high performance horses usually eat large amounts of concentrate two or three times a day. Motility of the gut becomes decreased as horses do not eat for more than 8 hours (Hodges and Pilliner, 1991) resulting in digestive disturbances, ulcers and increased stress levels in the horses. The horse's natural desire is to forage (Nicol, 1999). The prevention of this basic need can lead to unusual behavioural manifestations or vices (Nicol, 1999). This emphasizes the necessity to design stables and feeding systems that mimic the horse's natural feeding habits but at the same time ensures that the horses are receiving the desired nutrients to optimise performance.

Appetite and capacity for feed are also important considerations. These are regulated by four main factors. First, the volume of different parts of the gastro-intestinal tract (GIT) will control the physical amount that the horse can ingest. This is mainly controlled by the body size of the horse and to a small extent can be modified by adaptation. Secondly the rate of passage of ingesta will have an effect on capacity. The slower the food moves through the system the longer it will take for the horse to be hungry again. This can be manipulated through changing types and amounts of substrate fed. Thirdly, concentration of certain digestion products in the intestine will control meal size and finally, the energy demands of the horse will also affect appetite. Increased energy demands on race horses have led to the production of concentrate meals that contain high amounts of highly fermentable grains. As these grains ferment, high levels of gas in the caecum irritate the horse and the pH of the caecum drops to levels that are harmful to useful resident micro-organisms (Kohnke, 1998).

By considering the nutritional management of Thoroughbred race-horses in their training environment, many of the afore-mentioned factors can be seen to be manifest in the behaviour of the horse (Ellis & Hill, 2005). Any horse that is pedigreed and belongs to a particular breed can be “purebred”, but the Thoroughbred horse traces back to three foundation sires in the 17th Century and has been developed as a high performance speed and endurance animal throughout the world (Callery, 2003). The Thoroughbred is most commonly used in horse-racing, and the overflow from a relatively short racing career services other performance horse industries like eventing, dressage, showjumping, polo and polocrosse.

Thoroughbred race horses live in a controlled environment as they are invariably very expensive animals. They are fed very high concentrate diets, and have a hard training schedule. The aim of this dissertation is to ascertain whether the behaviour of Thoroughbred racehorses can be related to management strategies or is a result of the highly fermentable nature of the feed the horses are eating.

It is the writer’s opinion that incorrect feeding and management associated with feed and welfare will lead to physiological problems and behavioural disorders which in turn have the potential to reduce the horse’s athletic potential. This dissertation aims to highlight these facts and attempts to confirm the writer’s opinion by looking at the behaviour of horses in different management systems, specifically different feeding frequencies and different exercise intensities.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 PHYSIOLOGY OF THE EQUINE DIGESTIVE TRACT

Understanding the form and function of the gastro-intestinal tract (GIT) of the horse (Figure 1.1) is fundamental to a discussion of feeding and nutrition of the horse (Frape, 1986). Whatever feeding system is used for horses, it cannot be effective if we do not understand the dynamic processes of digestion within the horse’s gut (Theodorou & France, 2000). In the horse, the physical form of the diet and the quantity of feed influence the rate of flow through the GIT. For example, pelleted diets will move through the system faster than chopped hay, fresh grass moves through faster than hay, and large meals will move through the GIT quicker than smaller meals thereby reducing the time for digestion on the substrate available (Frape, 1986).

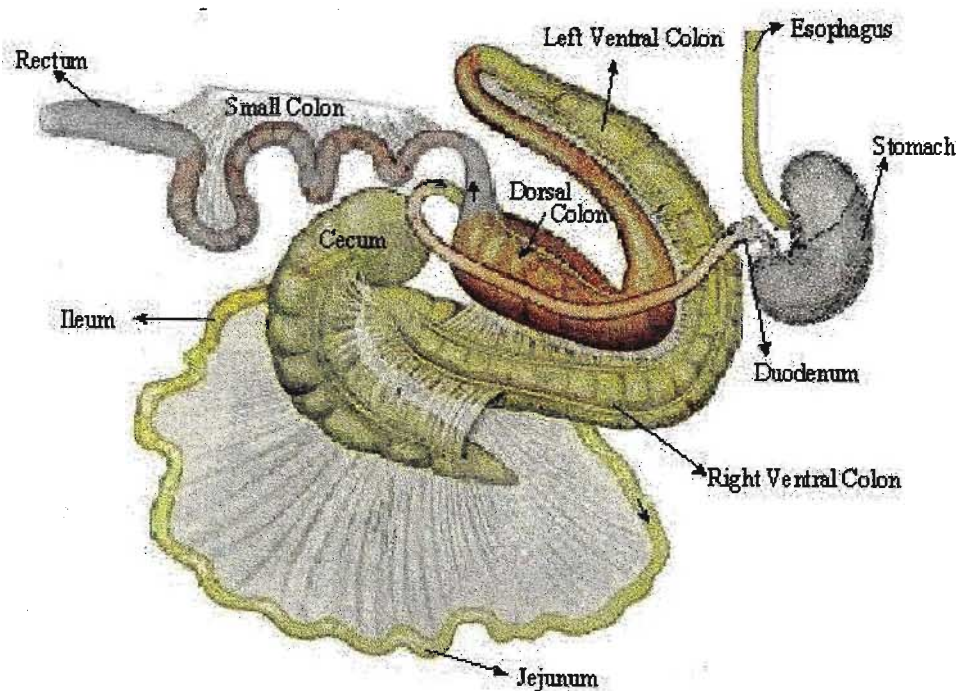


Figure 2.1 Digestive tract of a horse (Popesko and Saunders, 1977)

2.1.1 Upper digestive tract

Horses have strong upper lips that guide food to the teeth. Once the food is in the mouth, the tongue moves the feed to the cheek teeth for grinding. Lateral and vertical movements of the jaw,

accompanied by profuse salivation, result in the food particles being ground into small pieces coated with mucous suitable for swallowing. Grass and hay eaten by the horse must be ground to 1.6mm or less in length before being swallowed (Tiegs & Burger, 1993). If the mastication process is too short in duration there is a risk of abnormal behaviour such as crib-biting and wind sucking occurring, which can interfere with normal digestion (Krzak *et al.*, 1991). The presence of food in the mouth stimulates saliva production. Saliva contains the enzyme amylase, but in such low concentrations that it has very little impact on carbohydrate digestion (Tiegs & Burger, 1993). Rather it acts as a lubricant, coating food and enabling easy movement down the oesophagus into the horses' stomach. The saliva contains bicarbonate that acts as a buffer retarding the rate at which the pH of the substrate in the stomach will drop. In addition, the concentration of bicarbonate and sodium chloride in the saliva is proportional to the rate of secretion, and therefore increases during feeding (Tiegs & Burger, 1993). The bolus is moved by peristalsis down the oesophagus to the horses' stomach (Krzak *et al.*, 1991).

The horses' stomach makes up only 8-10% of the total GIT capacity and it has a volume of 7-15 litres (Krzak *et al.*, 1991). At the junction between the stomach and the oesophagus there is a sphincter that makes it almost impossible for horses to bring food up from the stomach into the oesophagus. As a result, stomach distension will often result in rupturing of the stomach lining (Tiegs & Burger, 1993). Feed spends a short time in the stomach but the stomach is rarely empty due to the continuous feeding habits of the horse (Kohnke, 1998). The rate of passage through the stomach can be increased as food quantities are increased, with a large meal moving through the stomach within fifteen minutes of consumption, reducing protein digestion, for example. Dietary fibre can retard the rate of passage (Cuddeford *et al.*, 1995).

In the stomach the food is mixed with pepsin and hydrochloric acid to break down solid food particles (Kohnke, 1998). Lactic-acid-forming bacteria are present in the upper parts of the stomach to help with fermentation of carbohydrates (Cuddeford, 1996). If lactic acid levels get too high, paralysis of the pyloric sphincter can result, and the stomach can burst from excessive gas production thorough bacterial fermentation (Cuddeford, 1996).

A full stomach will press onto the diaphragm of the horse and cause shortness of breath (Kohnke, 1998). This is a primary reason why horses should not be worked directly after feeding.

Approximately 10-30 litres of gastric juice are secreted daily and, as with saliva, is stimulated by the physical presence of food and not just the sight of food (Kohnke, 1998).

The small intestine is the major organ of digestion in the horse making up 28% of the GIT and is approximately 21 meters in length (Kohnke, 1998). It is divided into the duodenum, jejunum and ileum. Bile ducts and pancreatic ducts open into the duodenum. Here pancreatic enzymes, trypsin, lipases and amylases, break down protein, fat and carbohydrates, and bile from the liver emulsifies fat for absorption through the intestinal wall (Cuddeford, 1996). Bile will constantly flow from the liver into the small intestine because the horse has no gall bladder in which to store the bile (Cuddeford, 1996). Nearly 50-70% of all carbohydrate digestion and absorption and almost all amino acid (AA) absorption will occur in the small intestine (Kohnke, 1998). Fat soluble vitamins A, D, E and K are absorbed here along with the B vitamins, calcium and some phosphorus. It will take between 30-90 minutes for the food to pass through the small intestine (Frape, 1994). The contents of the small intestine are usually quite fluid (4-8% dry matter) depending on the ration. Digesta is propelled quickly through the intestine of an adult horse and can reach the caecum as quickly as 45 minutes after a meal (Frape, 1994). The feed material that leaves the small intestine is described as fibrous feed residues, undigested feed starch and protein, micro-organisms, intestinal secretions and cell debris (Frape, 1994).

The large intestine is about seven meters long and is divided into the caecum, right ventral colon, left ventral colon, right dorsal colon, transverse colon, small colon and rectum (Kohnke, 1998).

2.1.2 Caecum

A characteristic of all grazing and browsing animals is the enlargement of some part of their GIT to accommodate fermentation of digesta by micro-organisms (Frape, 1986). Approximately 20% of the animal's live weight is made up by the gut, mostly due to the caecum and colon (Kohnke, 1998). No mammal secretes enzymes capable of breaking down the complex molecules of cellulose, hemi-cellulose, pectin and lignin for absorption, but with the exception of lignin, intestinal bacteria can break the bonds in these complexes and make them suitable for absorption and utilization by the horse (Cuddeford, 1996). This process is slow compared to the speed at which starch and protein is digested. This means that the rate of flow of digesta has to be reduced to allow for sufficient time for the bacteria to have a significant impact on the substrate material (Cuddeford, 1996).

The caecum is a large organ about three meters long with an approximate 30-litre volume (Kohnke, 1998). It functions in a similar manner to a rumen (Cuddeford *et al.*, 1995). Here microbial fermentation of feed occurs. The entrance and the exit to the caecum are both at the top of the

organ. This anatomical feature can cause problems if the horse eats large quantities of dry food without adequate water or if the diet is changed too rapidly (Kohnke, 1998). This can lead to compaction and colic (Cuddeford, 1996). In the caecum, cellulose and other indigestible carbohydrates are broken down into volatile fatty acids (VFA's), which are an important energy substrate for the horse (Cuddeford, 1996). The type and amount of microbes in the caecum is dependant on the type and amount of food being eaten (Kohnke, 1998). These microbes are very sensitive to changes in the diet and serious metabolic problems such as diarrhoea, colic and constipation can result from sudden dietary changes (Pearce, 1975; Ellis & Hill, 2005). Caecal bacteria from horses adapted to a grain diet are less efficient at digesting hay than are the microbes from hay-adapted horses (Pearce, 1975). The bacteria in the caecum are responsible for the degradation of dietary fibre, starch and protein. These processes yield large amounts of short chain VFA's as by-products (mainly acetic, propionic and butyric acids) (Pearce, 1975). The contents of the caecum are not buffered by saliva in the same way as rumen contents and are therefore susceptible to the accumulation of these organic acids that are associated with rapid fermentation of sugars and starch (Kohnke, 1998). These acid levels if not controlled would quickly make the caecum an uninhabitable environment for the microbes (Cuddeford, 1996). A change in the ratio of starch to fibre in the diet leads to a change in the proportions of the various volatile acids produced. Proportionally, more propionate is produced as a result of the consumption of a starch diet (Robinson and Slade, 1974). All VFA's pass easily into the blood. However, lactic acid that is produced in the stomach is not well absorbed in the small intestine (Robinson and Slade, 1974). It is converted into propionate by the caecal bacteria and absorbed in the caecum. Microbial bacteria synthesize water-soluble vitamins (Kohnke, 1998). For this reason the amount of vitamin B in the faeces is higher than the level in the given feed. The dry matter of material in the caecum is between six and ten percent (Frape, 1986).

Excess amounts of fermentable sugars and starches in high grain diets or in good pasture can overload into the hindgut. This results in the production of excess amounts of d-lactic acid which leads to caecal acidosis. If the caecal pH falls below 6.4 the useful micro-organisms in the caecum die resulting in low grade diarrhoea and passing of "cow pat" like droppings containing undigested grains (Kohnke, 1998). This decrease in caecal pH increases the likelihood of "hot" or nervous behaviour in horses on high grain diets due to a simultaneous increase in the amount of gas produced due to fermentation of grains in the hind-gut causing irritation to the horse (Willard *et al.*, 1977; Ellis & Hill, 2005).

Microbial activity in the caecum produces gases, mainly carbon dioxide, methane and small amounts of hydrogen. These are normally absorbed, ejected from the anus or participate in further metabolism. These gases can cause severe problems like colic, where production rates exceed dispersal rate (Frape, 1986).

2.1.3 Lower digestive tract

The dry matter content of the ingesta increases as it travels from the caecum to the rectum (Frape, 1986). Food reaches the colon approximately seven hours after ingestion and can remain for up to 65 hours (Pearce, 1975; Ellis & Hill, 2005). Microbial digestion continues in this region and nutrients made available through caecal fermentation are absorbed (Kohnke, 1998). Vitamins, water and fatty acids are also absorbed. The faecal balls, which should consist of the indigestible portion of what was fed, will move from the lower digestive tract to the rectum for excretion (Kohnke, 1998).

2.2 A COMPARISON OF DIGESTION IN RUMINANTS AND HORSES

Both hindgut and foregut fermentation achieve the same purpose in digesting the cellulose of otherwise indigestible plant cell walls via microbial fermentation (Cuddeford, 1996). However there are some major differences between the two methods. Fermentation occurs in the enlarged cardiac region of the stomach of foregut fermenters (ruminants), while in hindgut fermenters, the caecum becomes enlarged to allow the bacterial fermentation (Hintz *et al.*, 1971; Ellis & Hill, 2005). Because foregut fermentation precedes enzymatic digestion in the small intestine, it has many advantages over hindgut fermentation (Kohnke, 1998). By allowing the microbes to digest and synthesize before the enzymatic digestion, the microbial cells can be utilized via digestion in the small intestine; in hindgut fermentation, those cells are lost in the faeces. To obtain all the nutrients lost in this way, hindgut fermenters practice coprophagy, which means that they ingest faeces to obtain all the nutrients from fermentation (Kohnke, 1998). Foregut fermenters are also far less dependent on the quality of protein in feeds because bacteria have the ability to synthesize high-quality proteins from non-protein or low quality sources. Many plant toxins are also frequently degraded in the foregut via microbial fermentation, protecting the animal from potential harm (Hume, 1999). Highly lignified cell walls of very poor quality forages also pose less of a problem to foregut fermenters, and as a result the contents of the cells are more easily accessed and utilized by the microflora (Hume, 1999).

2.3 UTILIZATION AND DIGESTION OF ENERGY

2.3.1 Describing the energy content of horse feed

There are three main ways to describe the energy potential of a horse feed: total digestible nutrients (TDN), digestible energy (DE) and net energy (NE) (Harris, 2001).

2.3.1.1 Total Digestible Nutrients

TDN is a figure that indicates the energy value of a feed to an animal. TDN is calculated by the following equation (Schneider & Flatt, 1975; Ellis & Hill, 2005):

Equation 2.1 $TDN = \text{digestible CP} + \text{digestible CF} + \text{digestible NFE} + (\text{digestible EE} \times 2.25)$

where:

CP	=	crude protein
CF	=	crude fibre
NFE	=	nitrogen free extract
EE	=	ether extract

Conversion factors have been used to convert TDN values to today’s more commonly used DE values. However, according to Harris (2001) these may not be appropriate. In the horse, limited work has been done in this area but research has shown that the conversion factor that was determined through work with ruminants is not adequate for calculations with horses (Harris, 2001). For this reason this method has become the least popular (Lindsay, 2005).

2.3.1.2 Digestible Energy

The energy content of horse feed is usually referred to in terms of DE (Harris, 2001). This is the gross energy (GE) in the feed minus the energy lost in the faeces (Harris, 2001). A DE estimate can be determined *in vivo*. However, this does not provide a truly accurate measurement because faecal energy includes energy originating from endogenous sources and bacteria as well as undigested feed (Harris, 2001).

2.3.1.3 Net Energy

NE is calculated as DE minus the energy lost as gas, energy lost in the urine and energy lost as heat waste for maintenance and production - also known as the heat increment of the feed (Harris, 2001). This system allows for the differences in utilization of ME available from different feeds, depending on the proportion of the end products of digestion produced and the biochemical pathways through which these end products are used to produce energy (Harris, 2001). It is essentially the energy available for life and movement (Harris, 2001). The NE system relies on the fact that the maintenance requirement for energy accounts for the largest part of the total energy requirement which may not be true for certain performance animals (Harris, 2001). NE is not a characteristic of a raw material, but more a characteristic of the compound ration. It is measured by feeding a particular diet and determining energy lost in the heat increment, either by calorimetry or by comparative slaughter technique. Of all the systems, NE most closely reflects the energy available for production and is desired by nutritionists when formulating diets. It is, however, the most difficult value to determine (Batterham, 1990).

2.3.2 Energy for exercise

An accurate estimate of body weight is very important when formulating rations for all horses. A horse in race training should be consuming 2.5 % body weight in dry matter (kg) (Kohnke, 1998). An equation (Huntington, 1991) for calculating body weight based on heart girth and length uses the following measurements:

$$\text{Equation 2.2} \quad \text{Body weight (kg)} = \frac{\text{Heart Girth}^2 \text{ (cm)} \times \text{Body Length (cm)}}{11,880}$$

Before a discussion on the energy requirements for exercise can take place the basic energy requirements for maintenance need to be established. Values for energy requirements are not based on metabolic size, as Pagan and Hintz (1986) have found no benefit in using metabolic body weight ($\text{kg}^{0.75}$) over weight (kg^1) in determining the energy requirements of horses ranging in size from 125 to 856 kg.

The maintenance requirements of a horse weighing 500kg can be estimated from the equation derived by Pagan and Hintz (1986):

Equation 2.3 $DE \text{ (MJ/day)} = (1.4 + 0.03BW) \times 4.184$

where: BW = weight of the horse (kg)

Energy requirements for maintenance and growth can be calculated using the following equation (Pagan and Hintz, 1986):

Equation 2.4 $DE \text{ (MJ/day)} = [DE \text{ (maintenance)} + (4.81 + 1.17z - 0.023z^2)] \times 4.184$

where: ADG = average daily gain (kg)
z = age of the horse (months)

The DE estimation for work for racehorses can be best determined using the following equation suggested by Ralston (1988):

Equation 2.5 $DE \text{ (MJ/day)} = (5.97 + 0.021BW + 5.03z - 0.48z^2) \times 4.184$

where: BW = weight of horse (kg)
z = Combined weight of horse, rider and tack (kg) multiplied by 10^{-3} .

The equation determined by Pagan and Hintz (1986) for horses confined to metabolism stalls is:

Equation 2.6 $DE \text{ (MJ/day)} = (0.975 + 0.021W) \times 4.184$

where: W = weight of the horse (kg)

The digestible energy requirements for maintenance for a horse with a mature weight over 600kg can be estimated by the following equation (NRC, 1989):

Equation 2.7 $DE \text{ (MJ/day)} = (1.82 + 0.0383W - 0.000014W^2) \times 4.184$

where: W = weight of the horse (kg)

To accurately examine the substrates that give the horse energy it is essential to have an idea of the horse's requirements. The nutritional requirements of a 500 kg Thoroughbred horse in race training are shown in Table 1.1.

Table 2.1 *Nutrient requirements for mature horses with a bodyweight of 500kg (adapted from NRC, 1989; cited by Kohnke, 1998; Martin-Rosset, 2001; Jackson, 2002)*

	Wt (kg)	DE (MJ)	DE (MJ/kg)	TDN (kg)	Crude protein (g/day)	Lysine (g/day)	Calcium (g/day)	Phosphorus (g/day)	Daily feed (kg/day)
Maintenance	500	91.6	9.2	3.73	1000	25	23	14	7.45
Race training	500	110	11-13	3.74	1192	45	34	19	12.5

The amount of energy and the energy density (MJ/kg) of the diet increase dramatically from maintenance requirements as the work intensity increases. Underfeeding and energy deficiency in the horse will manifest as weight loss, dullness of coat and loss of vigour, chronic fatigue and a sour attitude about work (Jackson, 2002). Weight gain in the mature horse may indicate that energy in excess of that required is being consumed (Jackson, 2002).

The horse is unique in that it compensates for excess dietary energy intake by increasing its physical activity (Lewis, 1995) as well as gaining in body fat. The result of this is that a horse being fed over its energy requirement will be harder to control and more agitated in its stall. Frustrated horses are more likely to start using stereotypic behaviours as a release (Nicol, 1999).

Energy is required to fuel body processes, for muscles to work and to maintain the horse’s body-temperature. Estimates of energy in horses are usually given as units of digestible energy (DE) as compared to ruminants where energy is most often expressed as metabolisable energy (ME).

2.4 ESSENTIAL NUTRIENTS

2.4.1 Carbohydrates

The main source of energy for the horse comes from carbohydrates since approximately 75% of all plant matter is comprised of carbohydrates (Kronfeld, 2001). Carbohydrates are simple molecules that are straight chain aldehydes or ketones, with many hydroxyl groups added. One can distinguish, in the horse, between the sources of carbohydrate that can be processed by mammalian enzymes and those that need to be fermented (Kronfeld, 2001; Ellis & Hill, 2005). Hydrolyzed

carbohydrates yield mainly glucose, while fermented carbohydrates yield acetate, propionate and butyrate. Digestive and metabolic processes are more efficient for hydrolyzed carbohydrates than for fermented carbohydrates, which have to be fermented by microbial populations in the digestive tract of the horse (Ellis & Hill, 2005). Fermented carbohydrates should be further classified according to rate of fermentation (Kronfeld, 2001), i.e. slowly fermented fibres and rapidly fermented fibres. It is important to distinguish between the two because rapidly fermenting fibres tend to give rise to lactate rather than acetate and lactate is responsible for a drop in caecal pH and development of caecal acidosis and laminitis. Hind gut pH changes have also been connected to behavioural disorders through rapid fermentation resulting in excessive gas production in the hindgut irritating the horse (Willard *et al.*, 1977; Ellis & Hill, 2005).

Glucose is the main energy source for horses and ruminants fed high grain diets while VFA is the main energy source in horses fed high roughage diets (Roberts, 1975; Ellis & Hill, 2005). Horses given high grain diets will experience higher peaks and lower troughs of blood glucose than horses maintained on mainly roughage diets (Roberts, 1975; Lawrence *et al.*, 1993). The grain fed horse will be more energetic at peak blood glucose and usually less energetic at the trough (Frape, 1986). By increasing the feeding frequencies the cyclic changes in the blood glucose can be smoothed out (Frape, 1986). Excess energy can make a horse over energetic if it is an excitable horse or overweight if it is a quiet horse (Kohnke, 1998). Carbohydrate digestion is a more energy efficient method of producing glucose (Blaxter, 1967). Also produced are acetic, propionic and butyric VFA. Glucose and propionate are stored in the liver as glycogen. Acetate and butyrate are stored as fat. After a feed the concentration of blood glucose will rise above basal level (Argenzio & Hintz, 1972). Insulin, which increases as a result of the increase in blood glucose, aids in the storage of excess glucose as depot fat or muscle glycogen (Argenzio & Hintz, 1972). This prevents glucose that will be needed as fuel later being lost in urine (Frape, 1986). Blood glucose peaks about three to eight hours after feeding and returns to basal level within two hours (Argenzio & Hintz, 1972). Insulin levels peak shortly after the glucose peak occurs. The time from glucose peak to return to basal is called tolerance time. Thoroughbreds are more sensitive to insulin and the insulin activity of the blood than ponies that have a longer tolerance time. This means that ponies can go without food for a longer time period than Thoroughbreds and accounts for why Thoroughbreds become more excitable after eating (Frape, 1986). Horses accustomed to high starch diets have high insulin activity and will be more inclined to hypoglycaemic shock when fasted. The insulin status of a horse can be determined by measuring glucose tolerance, which is the concentration of glucose that can be absorbed without causing glycosuria. Glycosuria is the presence of abnormal amounts of glucose in the urine. This condition can arise from diabetes mellitus, fasting or low starch diets

(Frape, 1986). Thoroughbred horses have a delayed insulin response following a carbohydrate feed (Kohnke, 1998). This can increase the chances of hot and nervy behaviour within four hours of eating a concentrated grain based feed (Kohnke, 1998). This behavioural reaction is increased as the size or bulk of the concentrate meal is increased (Kohnke, 1998).

Non-structural carbohydrates are those carbohydrates that occur as simple sugars in the feed and can be broken down by enzymes produced in the stomach and small intestine of the horse. These carbohydrates are nearly non-existent in hay but form a large part of high grain diets. This category of carbohydrates is made up of: glucose, fructose, lactose and starch. Structural carbohydrates have a cell wall. They are resistant to the horse's naturally-produced enzymes. These carbohydrates need to be fermented by bacteria in the hindgut of the horse. This group of carbohydrates consists of cellulose and hemi-cellulose. Cellulose digestion is dependant on rate of fermentation and retention time in the caecum (Harbers *et al.*, 1981). Carbohydrates can only be absorbed in the small intestine as monosaccharides. Starches are broken down into the disaccharide maltose by the enzyme amylase. Maltose, sucrose and lactose are split into the monosaccharide units by the enzymes maltase, sucrase and lactase that are produced by the small intestines brush border. These disaccharides are completely digested in the small intestine of a healthy horse. The horses' ability to produce amylase is limited resulting in a large proportion of starch escaping digestion in the small intestine and passing into the hindgut. The type of forage and time it is fed relative to grain can have a large effect on pre-caecal starch digestibility (Pagan, 1997). Meyer *et al.* (1993) in Pagan (1997) found that feeding grass hay instead of ground lucerne meal resulted in a decrease in the digestibility of pre-caecal starch of ground corn from 45% to 16%. This could have resulted because ground lucerne meal is not as effective as the hay at slowing down the rates of passage of the ground corn because of its fine structure. This emphasizes the importance of feeding good quality long stem roughage to increase rates of passage and optimise grain digestion before it reaches the hindgut (Willard *et al.*, 1977; Karlsson *et al.*, 2000).

2.4.2 Lipids

Dietary lipids can be an alternative source of energy in horses and provide essential fatty acids to improve skin and coat condition (Oldham *et al.*, 1990). Lipids are a class of hydrocarbon-containing organic compounds, which are cleaved into monoglycerides by lipases. Lipids are used for energy storage and as structural components of cell membranes. Fat can reduce the protein: energy ratio and allows for a reduction in the dietary starch content by making the ration nutrient dense (Hambleton *et al.*, 1980). Fats contain 2.25 times more energy per unit weight than

carbohydrates and proteins (Hambleton *et al.*, 1980). The main reason for feeding high fat diets to performance horses is to provide the horse with a high-energy easily digestible diet (Oldham *et al.*, 1990). Fats have a digestibility ranging from 76 to 94% (Pagan, 2002). Even at high levels dietary fat is digestible (Pagan, 2002). Hambleton *et al.* (1980), refers to an experiment where levels of up to 20% dietary fat were 90% digestible by the horse.

Both fats and proteins can be converted to glucose to fuels the horse's requirements (Kohnke, 1998). Protein does so through the conversion of the carbon chains of amino acids to intermediate chains and some of the carbon chains to glucose (Frape, 1986). Fat becomes hydrolysed to fatty acids and glycerol. The glycerol is then converted to glucose and the fatty acid broken down by beta-oxidation in the mitochondria, producing ATP and acetyl CoA (Frape, 1986).

The reason for using lipids as an energy source is to delay fatigue and reduce the incidence of digestive disorders related to high carbohydrate diets (Hambleton *et al.*, 1980). Research has shown that both rats and horses exhibit aerobic endurance when fed a high fat diet (Oldham *et al.*, 1990). According to Oldham *et al.* (1990), feeding a 10% fat supplemented diet will increase muscle glycogen storage in fit horses, and increase the amount of muscle glycogen utilized during an anaerobic workout. Metabolism of fats provides pyruvate to feed the aerobic pathway and delays blood glucose and glycogen depletion to maintain higher muscle reserves during extended exercise (Frape, 1986). Addition of 12% DE as fat has been reported to increase resting glucose concentrations by approximately 26% (Kohnke, 1998).

On an energy equivalent basis, one cup of vegetable oil contains the same amount of digestible energy as six cups of whole oats or three cups of crushed maize (Kohnke, 1998). This is a clear indicator of the potential benefits of fats in reducing the bulk and increasing the energy density of a racehorse feed. Horses are capable of digesting and utilising up to 30% of their energy need as fat, without developing digestive complications, provided it is slowly introduced to allow the equine body to adapt (Kohnke, 1998). Some examples of other sources of high fat energy substitutes include full fat soya, sunflower oil seed cake and sunflower seeds (Kohnke, 1998).

The reduction of gut fill on fat-boosted diets may lower hindgut fluid reserves trapped in the cellulose and lignin fibre structures of grains and hays. Fats and oils used in horse feed are high grade and therefore expensive. Oils added to horse feeds must be properly stored to avoid rancidity. Commercially produced feeds with high levels of fat deteriorate quickly in storage (McDonald, *et al.*, 1995).

2.4.3 Protein

Protein provides the amino acids needed for muscle growth and repair of body tissues (Frape, 1994) and is constructed from the combination of amino acid monomer units (Ellis & Hill, 2005). Horses require increased dietary protein when they are growing, pregnant or lactating (Frape, 1975). A deficiency of protein will result in slower growth rate, weight loss, reduced performance and lack of muscle development and stamina in a mature horse (Frape, 1975; Kohnke, 1998).

Feed proteins are broken down into amino acids by enzymes in the small intestine. There are 22 amino acids that recombine during metabolism to produce the specific proteins for muscle, blood, skin hair and other tissues of the horse's body (Frape, 1975). Non-essential amino acids can be synthesised by the body. About half of the amino acids are essential and need to be supplied in the horse's diet (Slade *et al.*, 1971; Ellis & Hill, 2005). There is scope for research into the amino acid profile of horses. Because horses are not fed for maximum growth but rather for performance and often for leisure, little research has been done in the area of amino acid requirements of the horse. Excess protein is broken down to ammonia and amino acids by bacterial fermentation in the hindgut (Slade *et al.*, 1971). This kind of fermentation produces six times more heat waste than carbohydrate fermentation (Slade *et al.*, 1971). However, limited ammonia and almost no amino acids are absorbed as nitrogen sources from the hindgut (Frank *et al.*, 1987).

The horse's daily protein requirement is increased through work. Protein deficiency in horses is rare and under stabled conditions, protein excesses are more likely to occur (Pagan, 2002). Provided sufficient energy is available to racehorses, they can perform adequately on rations containing 12-14% crude protein. According to Pagan (2002) the present NRC requirement is reasonable for a 500kg horse. An increased intake of good quality protein may be beneficial during early training as muscle mass and blood cell production is increased. The day after a heavy race, a higher protein level in the feed may help repair of muscle tissue (Kohnke, 1998). There is however a negative effect associated with excess protein in the rations. Good quality protein feed additives are expensive and high levels of protein in the ration lead to an increase in urine production to help remove excess ammonia from the horse's system. Increased urine production leads to increased water intake, wetter stalls and an increased cost for bedding materials. In poorly ventilated stables this will result in a build up of ammonia and possible respiratory problems in the horses (Nielson, 2001). One study that looked specifically at feeding two concentrations of protein (10 and 20%) to two-year-old horses in training found no consistent benefits or detrimental effects in feeding the higher concentration of protein (Frank *et al.*, 1987).

Urea can be tolerated up to 5% in horses' diets (Slade *et al.*, 1971). Urea can be synthesized in a horse's liver from excess protein in the diet and secreted back into the intestines as a nitrogen source, or excreted by the kidneys (Reitnour and Treece, 1971). Feeds containing urea for sheep and cattle can be fed to horses, as horses can actually tolerate higher urea levels than ruminants, but the urea content is of no benefit to the horse (Slade *et al.*, 1971). Bacteria in the hind gut breakdown the urea to form protein, but no protein absorption occurs in this region. Excess nitrogen as urea in the blood can be converted to ammonia, which can result in nervousness and airway irritation, ultimately affecting athletic performance (Slade *et al.*, 1971).

2.4.4 Fibre

The roughage portion of the horses' diet is the most natural portion as horses are originally forage eaters only (Kohnke, 1998). Essentially, fibre pertains to any description of the structural polysaccharides in plant cell walls (Ellis & Hill, 2005). Horses require 25-30% crude fibre in the diet for efficient digestion (Roberts, 1975). The enzymes released in the small intestine digest only the soluble portion of the dietary fibre. The rest of the fibre passes into the hindgut where enzymes released by the bacterial flora during fermentation break the carbohydrate into short chain fatty acids that are absorbed and provide a source of energy during metabolism (Roberts, 1975). Since fermentation occurs long after the meal has been eaten, the products of fibre fermentation can be used hours after the ration is given (Roberts, 1975).

Lignin, an insoluble fibre found in the woody stems of mature plants and husks of grain, is resistant to bacterial fermentation (Roberts, 1975). Instead it helps maintain the motility of the digestive system and dilutes the highly soluble sugar and starch that can overload the hindgut (Roberts, 1975).

For fibre analysis the terms acid detergent fibre (ADF) and neutral detergent fibre (NDF) will be used. NDF is the component of the feed that is lignin, cellulose and hemi-cellulose (Cone *et al.*, 1998). The ADF portion includes only cellulose and lignin (Cone *et al.*, 1998). The higher the NDF and ADF values of the ration, the less digestible the feed will be (Cone *et al.*, 1998).

Horses have a strong desire to spend time foraging and chewing (Kohnke, 1998). This desire can be easily satisfied through the provision of long stem forage sources (Kohnke, 1998). Wood chewing is a vice that is caused by lack of long stem fibre in the diet (Davies, 1995).

2.4.5 Water

Water is not often classified as a nutrient even though it makes up two-thirds of the body mass of adult animals and accounts for more than 99% of the molecules in the body (Church and Pond, 1988). Water losses occur through urine and faeces, through vaporization from the lungs and dissipation through the skin, and by sweat through the sweat glands in the skin (Church and Pond, 1988). Water requirements vary with the type and amount of ration fed, the amount of work the horse is doing and the environmental temperature (Pearce, 1975). Water intake will be increased after hard work and after the ingestion of roughages (Zeitler-Feicht, 2001).

As the work load of horses is increased, there is an increase in sweating rates. While being ridden 9.6km daily, Thoroughbred horses have been reported to have sweat losses of 15.6g/kg of body weight (Hoyt *et al.*, 1995), while almost 40 litres of water have been reported to have been lost during an 80km endurance ride (Snow *et al.*, 1982).

2.4.6 Vitamins and minerals

Vitamins are organic compounds that are required in very low concentrations to promote and regulate biological processes in the body, while minerals play an important role in metabolism (Ellis & Hill, 2005). Horses require adequate and balanced intake of minerals (Frape, 1986). The minerals that are involved in structural components of bone, muscle blood and other tissues are calcium, phosphorus, copper, magnesium and iron. Those involved in metabolic activity include manganese and zinc and in energy utilization, calcium and iron (Frape, 1986; Kohnke, 1998).

Calcium is absorbed in the small intestine and phosphorus is absorbed in the large intestine. Diets consisting of predominantly cereals are generally found to be high in phosphorus and deficient in calcium (Hintz & Schreyver, 1972). The optimum ratio of calcium and phosphorus is generally accepted as 1:1 (Pearce, 1975), but Schreyver *et al.* (1970) suggested that more calcium than phosphorus should be fed. Hintz & Schreyver (1973) concluded that horses can tolerate ratios from 1:1 to 4:1 provided that adequate amounts of both calcium and magnesium are provided in the diet. Large amounts of dietary phosphorus will reduce the absorption of magnesium (Hintz & Schreyver, 1972). Magnesium is found in Lucerne and is an easily digestible mineral (Hintz & Schreyver, 1972). Potassium is available to horses in the form of hay (Frape, 1986). Sodium can be added to the stabled horse's diet through salt licks (Kohnke, 1998).

Vitamins are required only in small amounts but are vital to the health and performance of all horses (Pearce, 1975). Vitamins are classified as fat soluble and water soluble (Pearce, 1975). Fat soluble vitamins (Vitamins A, D, E and K) are found in good quality pasture and sun dried hay. The B-group vitamins are all water soluble and are synthesised along with additional Vitamin K by bacterial fermentation of fibre in the hindgut. Vitamin D is also synthesised in the skin by sunlight and Vitamin C synthesised in the liver and other tissues (Kohnke, 1998). According to Astrand & Rodahl (1970) there is no benefit or advantage gained to the horse's performance by feeding vitamins above that of their requirement.

Horses do not exhibit nutritional wisdom (Frape, 1986) so it is essential to control the intakes of vitamins and minerals. The reader is encouraged to reference Ellis & Hill (2005) for a more in depth consideration of vitamins and minerals.

2.5 COMMON FEED INGREDIENTS IN EQUINE RATIONS

It has been shown that each feed ingredient used in rations results in a different response within the horse (Kohnke, 1998; Marsden, 1993; Pilliner, 1992). Grains are highly fermentable whereas roughages are not. Some grains are more fermentable than others and some roughage are better suited to some horses than others. These factors in turn affect the behaviour and physiology of the horse itself. This chapter looks at some of the main feed ingredients fed to Thoroughbred racehorses in the South African racing industry today and the effects that inclusion in the ration has on the horse itself. The analysis of the feeds tabulated in this chapter will vary according to processing and often the stage of harvest (Ewing, 1997); however the tables in this chapter are intended to give the reader a general over view of the feeds discussed.

2.5.1 Grains

Under certain performance conditions, the nutrient requirement of horses exceeds those provided by forage alone (NRC, 1989). For that reason cereal grains, maize and oats are fed to meet nutritional requirements (Hussein *et al.*, 2004) and provide substrate for muscle glycogen replenishment (Jose-Cunilleras *et al.*, 2004). Horses have been proven to show preference to common grains in the following order: oats, maize, wheat then barley (Kohnke, 1998). However once a horse is accustomed to a particular grain in the diet it may choose it over a better tasting, less known grain (Kohnke, 1998). Feeding oats and maize in proportion to the horses' energy

demands will not result in over energetic behaviour from the horse, however, excess grain, in any form, will make the horse excitable, increase the incidences of stable vices (Krzak *et al.*, 1991) and dispose horses to health risks such as colic, laminitis and academia (Hussein *et al.*, 2004).

The source of the carbohydrate will affect pre-ileal starch digestibility (Meyer *et al.*, 1993). Each kind of grain has a different structure of starch molecule. Oats contain the most digestible form of starch, followed by sorghum, maize and barley. These differences can be explained on the basis of the differences between the starch granules contained in the different plant materials; oat starch granules are small and easily digested. In work done by Meyer *et al.* (1993), it was found that pre-ileal digestibility of oat starch (80-90%), regardless of preparation, was significantly higher than that of whole or crushed corn (30%) or barley (26%). Grinding of corn in this particular experiment increased pre-ileal digestibility from 30 - 51%. Fombelle *et al.* (2004) found that oat and wheat starch had a very high digestibility of above 99%. These results show that these cereals can be safely fed to horses as only a very limited amount of the starch will reach the large intestine (Fombelle *et al.*, 2004).

The utilization of carbohydrates in grains that are not highly digestible is improved by processing of the grain. Grinding maize can increase digestibility from 30 - 45% and extruding maize improves digestibility to 90% (Kohnke, 1998).

In a review of starch digestion, Potter *et al.* (1992) found that as starch intake increased, small intestine starch digestibility declined. This relationship was later confirmed by Kienzle (1994). Potter *et al.* (1992) further suggested that in meal fed horses the upper limit of starch feeding should be 3.5–4g starch/kg body weight/meal. According to Medina *et al.* (2002), feeding 3.5g of starch/kg body weight exceeds the capacity of the small intestine to digest starch and allows non-degradable starch to reach the caecum where it is fermented quickly resulting in a low pH (Willard *et al.*, 1977). In a trial done by Bailey *et al.* (2002), it was found that addition of starch to *in vitro* caecal fluid over a 24-hour incubation period led to a significant decrease in pH (1.5 ± 0.2). This low pH in the hindgut has been shown to be a primary cause of laminitis in horses and has been implicated in some behavioural problems. In a previous trial, Willard *et al.* (1977) examined the effect of diet on caecal pH and feeding behaviour of horses. Results indicated that the increased caecal activity and narrowed acetate:propionate ratio associated with an all concentrate diet, significantly influenced the horse's desire to chew wood and practice coprophagy. In a paper by Rowe *et al.* (1995) it was found that behavioural changes characterised by chewing wood, eating bedding and wind-sucking were higher in horses fed high grain diets.

Grain fermentation by amylolytic bacterial species increases lactate production, decreases hindgut pH, fibre digestion and volatile fatty acid production (Hussein *et al.*, 2004). However Radicke *et al.* (1991) showed that different grains vary in the amount of lactate produced during caecal fermentation. It is important to avoid or decrease levels of grain that may be the cause of digestive or metabolic disorders due to their rapid starch fermentation. Improper management of grain feeding could predispose horses to health risks, such as colic, laminitis or post-feeding acidemia (Hussein *et al.*, 2004). In a study done by Medina *et al.* (2002), the addition of a live yeast culture to a high grain feed, led to a reduction in the pH drop and a decrease in lactic acid production usually experienced in the hind gut after a starch overload.

Oats (Table 1.2) are the most popular grain to feed horses and are the safest in terms of reducing incidence of acidosis (Ewing, 1997; Huntington, 1991). They are easily digestible and palatable with relatively high oil content (64%) when compared to other cereals (Ewing, 1997). However, they are low in B group vitamins, low in vitamin A and low in some essential amino acids. Oats are best fed whole, however crushing or rolling can improve utilization in very young and old horses (Kohnke, 1998).

Maize (Table 1.2) is a high energy grain used most frequently for performance horses. It is very palatable, but there is a danger of caecal acidosis if maize is consumed in excess (Kohnke, 1998), and so maize should never make up more than 25% of any grain mix. Kohnke (1998) suggests that maize be reduced or excluded on days of reduced exercise. The maize seed is high in starch (650-700g/kg), Vitamin A and Vitamin E but low in protein (91g/kg), fibre and minerals (Ewing, 1997). Of particular interest in horse feed is the deficiency of lysine in maize. Maize is best fed crushed for maximal small intestine absorption (Ewing, 1997). Crushed maize should not be stored for more than four weeks as it absorbs water and will have a high likelihood of being contaminated by mycotoxins (Kohnke, 1998).

Barley (Table 1.2) is an angular grain with a fibrous outer coat (Ewing, 1997). It can be used to replace oats in highly-strung horses and during hot weather as it does not ferment as readily and therefore less heat is produced on its digestion (Kohnke, 1998). Barley is a very good energy source for horses that are prone to azoturia (Kohnke, 1998). As with most cereals, the protein quality of barley is poor with lysine in particular being deficient (Ewing, 1997). Barley is also low in Vitamin A, D, E and calcium (Ewing, 1997).

Wheat (Table 1.2) is a high-energy grain, but it is deficient in lysine and if fed finely ground can inhibit digestion (Ewing, 1997; Kohnke, 1998). Both oats (115g/kg) and wheat (113g/kg) are high in protein but do not make a good protein source as large quantities need to be ingested for the horse to receive the protein available and these large quantities will lead to excitable behaviour in the horse (Jackson, 2002). The readily fermentable carbohydrates present in wheat can cause acidosis when fed at high levels (Ewing, 1997).

Table 2.2 *Nutrient analysis of grains that are commonly used in horse feed (Adapted from Kohnke, 1998)*

Ingredient	Use	Digestible Energy (MJ/kg DM)	Crude Protein (g/kg DM)	Fat (g/kg DM)	Crude fibre (g/kg DM)	Calcium (g/kg DM)	Phosphorus (g/kg DM)
Oats	Energy Fibre	12.1	115.0	46.0	100.0	1.0	3.2
Maize	Energy	14.7	91.0	36.0	22.0	0.3	2.8
Barley	Energy Protein Fibre	13.1	110-120	18.0	60.0	0.6	3.4
Wheat	Energy	14.4	113.0	18.0	24.0	0.6	3.0

2.5.2 Sources of Protein and Fat

Soya bean meal (Table 1.3) is one of the best quality vegetable protein sources available (Ewing, 1997). It contains high quality proteins in particular it is high in lysine (Ewing, 1997). 95% of the nitrogen present is true protein, making soya bean meal ideal for all livestock including horses (Ewing, 1997). Soya bean meal is good for growing horses and horses in work (Kohnke, 1998).

Sunflower oilseed cake is highly palatable and improves coat condition (Ewing, 1997). It is low in most vitamins and there is a high risk of rancidity when storing feeds containing this (Kohnke, 1998). Whole sunflower seeds (Table 1.3) can also be fed, entire, cracked or soaked in water for older horses. Sunflower has good protein levels being rich in sulphur containing amino acids but low in lysine content (Ewing, 1997).

Polyunsaturated oils (Table 1.3) are highly palatable and improve coat condition as they are rich in linolenic acid (Ewing, 1997). They are also suitable for reducing the dustiness of a ration (Ewing, 1997). They should be given as an alternate energy source for nervous horses or during hot weather as they do not cause high amounts of heat to be released during digestion (Kohnke, 1998).

Table 2.3 *Nutrient analysis of proteins and lipid sources that are commonly included in horse feeds (Adapted from Kohnke, 1998)*

Ingredient	Uses	Digestible Energy (MJ/kg DM)	Crude Protein (g/kg DM)	Fibre (g/kg DM)	Calcium (g/kg DM)	Phosphorus (g/kg DM)
Soya bean meal	Protein	13.1	445.0	62.0	3.6	6.3
Sunflower seeds	Energy	18.7	230.0	290.0	2.0	6.0
	Protein					
	Energy					
	Linoleic acid					
Polyunsaturated oil	'Cool' energy	37.7	-	-	-	-

2.5.3 Roughages

Generally, as the amount of roughage in the diet decreases, the less time the horse spends eating (Kohnke, 1998). Feeding a horse concentrates therefore increases leisure time, which in the confines of a stable is often spent on boredom related vices (Marsden, 2002). Large volumes of bulky, mature fibrous feeds may increase overall digestibility as the rate of passage through the gut is decreased, and the time for bacterial fermentation of fibre is increased (Ellis & Hill, 2005).

By feeding lucerne, the rate of flow through the GIT is slowed down (Kohnke, 1998). This reduces the risk of digestive disorders and increases the eating time and overall digestibility of the ration in the stable confined horse (Willard *et al.*, 1977). The incidence of stable vices and boredom related problems are lower when horses are fed rations containing high levels of Lucerne or roughages that slow the rate of passage through the GIT (McGreevy *et al.*, 1995a). Lucerne (Table 1.4) is highly palatable and a good quality protein and vitamin source (Ewing, 1997). It is a good source of calcium and vitamin D, however due to vitamin E antagonist in the lucerne; it reduces the amount of vitamin E absorbed by the horse.

Wheat bran (Table 1.4) is high in phosphorus and increases the palatability of the ration. It is low in energy, calcium and vitamins A and D (Kohnke, 1998). Wheat bran can be an expensive ingredient and should not contribute more than 10% of the entire ration. Wheat bran is not an essential ingredient in a horse feed, but it is useful for mixing supplements into the feed with molasses as it is so highly palatable (Kohnke, 1998). Oat hulls (Table 1.4) are a palatable and cheap fibre source, they are however low in nutritional value and can cause mouth lacerations (Ewing, 1997).

Eragrostis curvula (Table 1.4) is a good source of roughage. It is palatable and a good protein source if the quality is good. Veld hay (Table 1.4) is a cheap roughage source. It is very high in fibre and caution must be taken to only buy good quality veld hay as it could contain toxic plants accidentally cut and baled with the hay.

The importance of the roughage:concentrate ratio is emphasized in horse nutrition literature (Frape, 1975; NRC, 1989; Kohnke, 1998; Ellis & Hill, 2005). Thoroughbred racehorses should be eating 60% concentrate and 40% roughage. This dissertation looks at the consequences on gas production, hindgut pH alterations and horse behaviour when this ratio is altered.

Table 2.4 *Nutrient analysis of roughages that are commonly included in horse feeds (Adapted from Kohnke, 1998)*

Ingredient	Uses	Digestible Energy (MJ/kg DM)	Crude protein (g/kg DM)	Fibre (g/kg DM)	Calcium (g/kg DM)	Phosphorus (g/kg DM)
Lucerne hay	Fibre Protein	9.0-9.5	170.0	260.0- 280.0	12-14	2-3
Wheat bran	Fibre	11.1-11.4	150.0- 160.0	100.0- 150.0	1.2-1.6	10-12
Oat hulls	Fibre	6.8-7.2	38.0	310.0- 330.0	1-2	2-3
<i>Eragrostis curvula</i>	Fibre	8.0-10.0	84.0	273.0	0.33	0.22
Veld hay	Fibre	3.5-6.0	45.4	400.0	0.22	0.17

2.6 PHYSIOLOGICAL PROBLEMS ASSOCIATED WITH INCORRECT FEEDING PRACTICES

Many diet related problems will be expressed as either stereotypic behaviour or physiological problems in the stabled horse (Frape, 1975). Most common ailments and problems associated with feeding result from boredom and confinement, irregular feeding times, restriction of social interaction between horses at feed times, the feeding of highly concentrated rations that are quickly consumed, inadequate roughage and lack of opportunity for self-exercise or regular exercise (Kohnke, 1998). There are a number of serious disorders associated with horses consuming high levels of grain and soluble carbohydrates and while the consequences of grain feeding are diverse, it is almost certain that the primary cause is the development of acidic conditions in the hindgut (Willard *et al.*, 1977).

2.6.1 Colic

Abdominal pain in the horse indicates colic (Kohnke, 1998). There are four kinds of medical colic: gastric, spasmodic, tympanitic and food impactions (Hayes, 1994).

- Gastric colic

Over-distension of the horse's stomach causes gastric colic (Hayes, 1994, Krzak *et al.*, 1991). The horse's stomach, as mentioned before, is small in size (Frape, 1986). For this reason it is important never to over-feed the horse.

- Spasmodic colic

Spasmodic colic occurs when peristalsis of the gut is disturbed (Hayes, 1994). Peristalsis keeps the ingesta moving smoothly through the gastric tract. Disruption of the normal pattern can cause violent and irregular pain in the horse (Hayes, 1994). Causes of spasmodic colic include intestinal parasite damage, a sudden dietary change, irregular feeding, fatigue or anxiety (Hayes, 1994) or a sudden intake of water by a hot horse after exercise (Kohnke, 1998).

- Tympanitic colic

Tympanitic colic occurs when the horse eats unsuitable foods that lead to an accumulation of gas in the intestine (Hayes, 1994). A gas filled intestine is very painful and more likely to twist than a normal intestine (Hayes, 1994).

- Food impactions

Food impactions are the main concern in a stabled horse. In the wild, small amounts of food pass continuously through the GIT (Kohnke, 1998). In the stabled horse where food intake is controlled and horses are often over fed, this form of colic is a concern. This type of colic occurs mainly where there is either a change in the diameter of the colon or at flexures in the colon where the gut changes direction sharply (Hayes, 1994).

Attempts to control colic include correct de-worming programs, using only fresh, good quality feed, making gradual changes to the feeding programs, by not working horses for at least an hour after feeding and not feeding directly after heavy work.

2.6.2 Enteritis

This is an inflammation of the intestine characterized by diarrhoea. It is associated with overfeeding of very high protein feeds, a sudden change in feed, over working the horse to a point of over fatigue, poisoning (arsenic, lead, antimony, perchloride of mercury) or high worm burdens (strongyles in particular) (Hayes, 1994). Increasing roughage in the diet and fluid and electrolyte replacement will help horses with diarrhoea (Kohnke, 1998). Restoration of the normal hindgut

bacterial population is very important. This can be achieved through the use of probiotics (Rowe *et al.*, 1995). Probiotic feed additives consist of selected strains of lactobacilli and streptococci that alter the microbial species present in the GIT to the benefit of the animal (Fraser *et al.*, 1991).

2.6.3 Choke

Choke is a partial or complete blockage of the oesophagus. It can be due to horses eating their food too quickly, so that it is not adequately chewed and moistened (Pilliner, 1992). It can also be due to a teeth problem reducing efficiency of chewing (Pilliner, 1992). To prevent horses bolting down their food and getting choke, smaller meals should be offered more frequently. A racehorse trainer (2004, G. Werner, Pers. Comm.) from the Ashburton training facility in Ashburton near Pietermaritzburg, KwaZulu-Natal, suggested putting a large stone in the horses feed bowl to slow the horses feeding down as the horse has to push the stone around to get at all the feed.

2.6.4 Exertional Myopathy Syndrome

This condition is also called azoturia or tying-up (Fraser *et al.*, 1991). It occurs soon after the onset of exercise, particularly in fit horses, maintained on a full ration, the day after a rest. It is a result of carbohydrate overloading into the hindgut due to the feeding of high grain rations. Azoturia is an indication of poor management and usually occurs within the first hour of exercise. Large amounts of glycogen are present in the muscle. During anaerobic exercise, lactic acid will accumulate in the muscle at a rate exceeding the rate of its removal in the blood. The fall in muscle pH causes a coagulation of muscle protein and liberation of myoglobin, which escapes in the urine. The result is muscle damage, releasing muscle enzymes (CPK and AST) into the blood stream. Lactic acid is also released from the muscle cells and continuing to work even a mildly affected horse can worsen the condition (Fraser *et al.*, 1991).

Mares and fillies, especially when they are in oestrous, and nervous horses are most susceptible to this condition (Rees, 1984). Treatment involves reduction of pain and inflammation. Prevention is through careful stable management and attention to diet. Grain intake should be reduced to one third on rest days, starting the night before the rest day. Reduce levels of oats and maize in nervous fillies, replacing with an energy source that releases less heat on digestion or an extruded feed. It is important to remember to feed horses to their exercise levels – do not suddenly increase grains. Vegetable oil can be substituted in small amounts for grain (Frape, 1975).

2.6.5 Laminitis

This is a condition where the laminae of the hooves become inflamed. It is also known as “Founder”. Fermentation of carbohydrates in the hindgut has been recognized as one of the primary events leading to acute laminitis in the horse (Bailey *et al.*, 2002). Hindgut acidity kills large numbers of useful bacteria and protozoa in the caecum and large intestine. The breakdown of these micro-organisms releases endotoxins into the blood. These toxins are thought to change the flow of blood with the hooves thus starving the laminae of oxygen and nutrition. This results in the weakening and subsequent death of the basement membranes that bond the pedal bone to the inner white line area of the hoof. Recent surveys indicate that up to 41% of horses on high grain diets that are not clinically lame, may have symptoms of sore feet, shortened stride, rings on the hoof wall, long flared hoof wall-sole margins around the toe, and easily broken away hoof wall margins. Often these horses have a digital pulse in the arteries behind the fetlock at rest prior to exercise, all of which are indicative of low grade or sub-clinical laminitis. Many of these horses have x-ray changes with slight pedal bone rotation, erosion of the pedal bone surface and loss of pedal bone calcification associated with mild forms of laminitis (Bailey *et al.*, 2002).

To avoid this painful condition occurring reduce grain content of the ration (Kohnke, 1998). Avoid excessive bulk of meals to ensure maximum digestive activity in the small intestine (Bailey *et al.*, 2002). Grain intake should be reduced to one-third on light workdays for horses that are in heavy training. Monitoring of faecal pH in horses on high grain diets is also recommended (Kohnke, 1998).

2.6.6 Gastric Ulcers

Equine gastric ulcers affect up to 90% of racehorses and 50% of horses in hard work that go off their feed have gastric ulceration (Kohnke, 1998; McClure, 2003). Ulcers are the result of the erosion of the lining of the stomach due to prolonged exposure to the normal acid in the stomach (McClure, 2003). Horse’s stomachs continually secrete acid, which can result in excess if there is no feed in the stomach to neutralise the acid (Kohnke, 1998). Stomach ulcers occur when horses are not fed regularly, such as stable confined horses only getting two large concentrate meals per day and when horses are fed high grain diets that produce large amounts of volatile fatty acids (McClure, 2003). Chronic administration of non-steroidal anti-inflammatory drugs such as phenylbutazone can decrease the production of the protective mucus layer, making the stomach more susceptible to ulcers (Fraser *et al.*, 1991). Stress can also increase the likelihood of ulcers

(McClure, 2003). Strenuous exercise has also been linked to ulcer formation because it decreases both the emptying function of the stomach and blood flow to the stomach (McClure, 2003).

Treatment is aimed at removing predisposing factors and controlling acid production in the stomach. Horses should be allowed *ad libitum* access to hay or grass and more frequent feedings. This will help buffer the acid in the stomach. Decreasing the amount of grains in the ration that contribute to acid production will also help reduce the incidence of ulcer formation (Frape, 1975).

2.7 BEHAVIOUR OF THE HORSE

2.7.1 Typical Behavioural Patterns of the Horse

Behaviour is a phenotypic feature (Mills & Nankervis, 1991). It is the result of the interaction between the environment and genetics at any given moment in time (Mills & Nankervis, 1991). Wild horses will spend up to 60% of their day feeding, grazing up to midnight and then starting again at dawn. Ralston (1984) found free-range ponies graze 10 to 12 hours per day in bouts of two to three hours. Bouts of grazing are separated by periods of resting and of movement or social activity (Ralston, 1984). During grazing the horses will maintain almost a constant forward movement. According to Ralston (1984) horses and ponies given free access to feed but confined to stables will naturally feed in a pattern similar to a free range horse. In the same experiment ponies fed a complete pelleted feed *ad libitum* spend 38% of a 24-hour period engaged in eating activities, consuming 10 ± 1 meals per day. Thoroughbred horses on a grain ration with free choice loose hay chose to eat 11 ± 3 meals in a 24-hour period. Neither horses nor ponies will voluntarily fast for more than three to five hours (Ralston, 1984). The longest naturally occurring fast occur between 01h00 and 06h00. In another experiment done by Ralston *et al.* (1979) it was reported that ponies ate a proportion of their total intakes as isolated nibbling bouts and that the ponies consumed between 9–12 meals in 24-hours. The intervals between feeding bouts in this experiment was found to last 84 ± 10 minutes. In this trial it was found that feeding activities were significantly reduced between 01h00 and 06h00. The inter-meal intervals during the day period appeared to be controlled by exogenous cues such as the presence of fresh feed or feeding by neighbouring animals. Sweeting *et al.* (1984) reported that significantly less food was consumed by ponies when visual contact with other ponies was reduced.

Bad habits known as vices often develop in stabled horses as a result of boredom (Rees, 1984; Kohnke, 1998). The typical confined Thoroughbred is provided with a balanced diet and water but with nothing to occupy itself with for the rest of the day. It is not known if it is a lack of activity, isolation from other horses or effects from management and the environment that cause vices in horses, but no vices seen in the stabled horse have ever been recorded in wild horses (Ralston, 1984).

Breakdown of general behaviour of horses in the wild (Davies, 1995):

- Grazing 60%
- Standing 20%
- Lying down 10%
- Other 10%

Pawing the floor or door, or kicking walls are common problems in stable confined horses (Kiley-Worthington, 1983). Boredom may also be responsible for vices such as rug- or wood-chewing, crib-biting and wind sucking (Henderson & Warren, 2001). Aggression between horses is more often seen in captivity than in the wild (Mills & Nankervis, 1991). Horses have a well-defined social order which is severely disrupted in a racehorse training yard where the turn over of horses is high and the horses are not able to interact normally and form bonds with each other. Biting over the door or fighting between stable partitions is common (McGreevy *et al.*, 1995a).

Horses need to be observed *in situ* to determine a standard behavioural pattern for a stabled horse. According to Sweeting *et al.* (1984) the time budgets of horses in stables are similar to those of feral horses even though management and environment are different. However to determine if feeding frequency affects the behavioural patterns of the stabled horse, it is important to closely examine behaviours in relation to exercise and feeding schedules.

An ethogram is an inventory of behaviours of a species with the behaviours organized into categories (Altman, 1974). The ethogram organizes the animals' behavioural range into a structure, which will enable scientists to discover how individual behaviours help the animal to survive, mate and reproduce (Altman, 1974; Lorenz, 1981). Ethograms allow scientists to speculate about the evolution of behaviour through comparisons of behavioural patterns among species of similar genetics. By observing the horses' behavioural patterns, it can be determined whether the behaviour exhibited is due to changes in the timing and quantity of the feed or a normal occurrence (Altman, 1974). When describing behaviour in an ethogram it is more scientific to give a

description of the action rather than any reference to function or motivation (Altman, 1974). When studying stereotypes sufficient data must be collected to ensure validity of the results. Large sample sizes will give a more accurate assessment of population means and will give a clearer picture of how individuals differ according to age and sex (Altman, 1974). When looking at stereotypes it is important to notice when they are performed. It has been shown in a number of animal species that stereotypes increase as feeding time approaches (Altman, 1974). According to Mason (1993) it is important to note the animal's age or its stage of development, along with the physical and social environment in which it is stabled, and its feeding regime. Information to be gathered before a trial begins include, the length of time the animal has been performing the stereotype, whether the stereotype is performed in situations other than the original one, and whether the stereotype is easily prevented, and finally a past history of the horse being studied is essential (Mason, 1993).

2.7.2 Abnormal Behaviour of the horse

Stabled or confined horses often exhibit behaviours, which are generally regarded as abnormal and undesirable. This has led to the suggestion that frustration of specific motivational systems, or the resulting aversion, may underlie stereotypes (Rushen *et al.*, 1993). Stereotypic behaviours, which are defined as unvarying, repetitive, and apparently functionless (Mason, 1991; Mason, 1993), include activities such as too rapid feed intakes, crib biting, wind-sucking, wood chewing and weaving to name but a few (Leuscher *et al.*, 1989). Stereotypes affect animals of all ages and disciplines. Roughly 8% of horses exhibit some form of stereotypy (Marsden, 2002). However, in racing stables, this figure is more than doubled to around 30% (Marsden, 2002). All horses are individuals but according to Rees (1984) the character differences shown at any point in the horses life are influenced by; genetic make up, effects of past experience and effects of present circumstances.

Compulsive behaviours can be classified according to the normal behaviour from which they are derived (Leuscher *et al.*, 1991); locomotory, oral, sexual, aggression based, cutaneous irritation and grooming or social behaviours (Table 1.5).

Table 2.5 *Origins of some stereotypic behaviours performed by horses confined to stables*
(Luescher *et al.*, 1991)

Oral	Locomotive	Cutaneous Irritation	Aggression	Sexual	Grooming/Social
Chewing	Pacing	Box kicking	Kicking stall	Masturbation	Excessive self grooming
Crib biting	Weaving	Self rubbing	Head extended	Flank biting	Tail and mane eating
Wind sucking	Pawing	Self biting	Ears back and nodding	Flank kicking	Tail rubbing
Wood chewing	Tail swishing	Head tossing			Body rubbing
Obsessive water drinking	Door kicking (front feet)	Head circling			Rug tearing
Licking environment	Kicking over water bucket	Head shaking			
Eating bedding	Digging holes in bedding	Tail swishing			
Grinding teeth	Stamping				
Licking lips					

Horses fed high concentrate diets have a higher chance of developing stereotypies than horses fed on forage diets (Waters *et al.*, 2002). Forages increase eating time providing the horse with a more stimulating environment (Kohnke, 1998). This kind of diet reduces boredom and time available for a stereotypic behaviour to develop (Kiley-Worthington, 1983).

In an experiment done by Henderson & Warren (2001), an Equiball™ (Figure 1.2) was used in an attempt to enrich the environment of horses exhibiting stereotypic behaviours. An Equiball™ is a cylindrical device designed to give small food rewards as it is pushed around the floor by the horse thus mimicking foraging behaviour. In this experiment the Equiball™ succeeded in reducing the incidence of stereotypic behaviour through a reduction in boredom and increasing opportunity for foraging-like behaviour. Kiley-Worthington (1983), however cautions that introducing a novel object or a change in the environment to improve conditions through stimulation can often stress the horse and lead to an increase in frequency of the stereotype.



Figure 2.2 *Photograph of a horse eating from an Equiball™ (Picture taken from Henderson and Warren, 2001)*

McBride & Cuddeford (2001) found that cortisol levels are significantly lower after a stereotypic behaviour compared to before. This indicated that these behaviours are calming to the horse and help the horse deal with its stressful environment. Trying to physically prevent the occurrence of stereotypies places the horse in continual stress. Instead of physically preventing stereotypic behaviours and causing the horse more stress, environmental distractions and altered feeding techniques need to be identified and addressed. In a study done by McGreevy and Nicol (1998a), horses prevented from windsucking for 24-hours by crib biting collars, resumed the behaviour at a higher rate than before when the collars were removed. This rebound pattern generally means the behaviour is involved in maintaining homeostasis (Nicol, 1987). In the paper by McGreevy and Nicol (1998b), they suggest that normal gut motility and feed transit times in crib-biting horses may depend on physical flushing by saliva associated with their crib-biting behaviour.

When a grain meal is fed, blood glucose level increases (Pagan, 1997). Horses evolved eating diets that were low in non-soluble carbohydrates, so in the wild they would not experience wide fluctuations in blood glucose and insulin (Pagan, 1997). In humans it has been suggested that many mental disorders are the result of uncontrollable fluctuations of brain glucose levels in conjunction with insulin resistance (Holden, 1995). Insulin resistance is common in certain horses, so according to Pagan (1997) it becomes conceivable that these horses may experience high levels of glucose and insulin in the brain and hence exhibit erratic and uncontrolled behaviour.

Behaviour and temperament problems associated with the oestrous cycle are common (Rees, 1984) and since most mares come into oestrous for five days every three weeks, understanding the signs of oestrous are very important. The main sign of oestrous is frequent, nervous looking urination, with vulva-winking and tail-raising. Many fillies and mares become difficult to handle when they are “in season” (Rees, 1984). Commonly observed signs associated oestrous may include: aggression, kicking, increased interest in nearby stallions and geldings, decreased cooperation, difficulty in handling, nervousness and anxiety and unpredictable behaviour (Rees, 1984). Geldings

vary in their degree of non-sexuality. Geldings cut late or cut so that the epididymus of the testis is left to produce some testosterone, often show some stallion-like behaviour (Rees, 1984).

In a paper written by Rowe *et al.* (1995), results indicated that adverse effects such as behaviour changes, associated with feeding high grain diets to horses, can be overcome by controlling the build up of acidity in the hindgut. Results showed the incidence of adverse behaviour to be closely related to faecal pH ($r = 0.96$). These results are consistent with Willard *et al.* (1977) who reported that behaviour such as wood chewing and eating bedding was closely related to the concentration of lactic acid in caecal contents and negatively related to caecal pH.

Mean caecal pH values were significantly lower after feeding a concentrate diet than for horses fed a hay diet in a trial by Willard *et al.* (1977). The horses in this trial that ate the hay-only diet spent more time eating their feed and significantly less time chewing wood, in coprophagy, and in searching for feed than horses receiving the concentrate diet. Simple correlations of the animal activity data and the caecal parameters measured revealed that the amount of time spent chewing wood was significantly related to caecal propionate ($r=0.63$), caecal lactate ($r=0.87$), caecal acetate ($r=-0.61$) and the amount of time spent eating ($r=-0.77$).

Feeding practices have been found to have a great effect on the incidence of abnormal behaviours (Marsden, 1993). Feed restrictions have been found to increase the incidences of stereotypic behaviours in pigs, sheep and poultry (Rushen *et al.*, 1993). Horses like to eat for a minimum of 16 hours a day (Ralston, 1984). However when fed pelleted rations horses were found to eat for only 1 to 2 hours per day (Rushen, 1985). The time horses would have spent eating is now available for the development of stereotypies. Rushen (1985) suggests that a lack of feed bulk could possibly be a fundamental instigator in the development of stereotypies.

In a study done by McGreevy *et al.* (1995a), it was found that offering roughage at frequent intervals could reduce the incidence of abnormal behaviour in a racing yard. It was also found that offering another source of roughage in addition to hay also reduced the risk of abnormal behaviour. This was attributed to the fact that providing a selection of roughage will be a better approximate the variety of food a horse will receive on pasture (McGreevy *et al.*, 1995b). Hughes and Duncan (1988) suggest that rather than the actual physical hunger causing the stereotypies to develop, stereotypies could arise from the increase in foraging behaviour that accompanies feed restrictions. Increasing the opportunity for foraging was found to reduce stereotypies in canaries, bears, walrus and primates (Rushen *et al.*, 1993).

In a survey done by McGreevy *et al.* (1995a) on Thoroughbred racehorses it was discovered that management factors associated with the amount of time spent in the stable showed the strongest associations with stereotypic behaviour. From the survey they revealed that the risk of horses performing abnormal behaviour increased as the amount of forage fell below 6.8kg/day; when bedding types other than straw were used; when the total number of horses in the yard were fewer than 75 and when hay, rather than other forage types was used. They also found that weaving peaked in yards with between 51 and 75 horses and wood chewing peaked in yards with between 26 and 50 horses. The presence of bars between stables rather than high brick walls was found to be related to a reduction in abnormal behaviours in general, especially wood chewing. There was however no significant reduction in weaving. Improved social contact has been known to decrease stereotypic behaviour. This includes horse-horse, horse-human or putting a companion animal such as a sheep in the stable (McBride & Cuddeford, 2001). Mirrors in the stable have also been known to reduce undesirable behaviours. Mirrors mimic social contact and provide environmental distraction for the horses (McAfee *et al.*, 2002).

Ralston *et al.* (1979) found that feeding rations high in protein led to an increase in wood chewing in ponies. This was attributed to a reduction in the total fibre content of the rations fed during this trial. McGreevy *et al.* (1995a) concluded from their survey that management factors related to the amount of time spent in the stable showed the strongest associations with stereotypic behaviours in training yards. In another survey done by McGreevy *et al.*, (1995b) they found that the management of horses outside their stables (such as exercise regimes) did not significantly affect the occurrence of stereotypic behaviour. In a study by Krzak *et al.* (1991), it was found that horses chewed more wood when they had not received a forty-five minute per day workout.

Stereotypic behaviours are thought to develop as a means of coping with a sub-optimal environment and therefore their development may be indicative of reduced welfare (Waters *et al.*, 2002). Stress and frustration are the main causes; however genetic predisposition is also a major contributing factor. It is estimated that 40% of horses are predisposed, and the prevalence of stereotypies within these families is between 13 and 67%, compared to 1 to 26% in non-predisposed families (Marsden, 2002). Luescher *et al.* (1991) believed that horses inherit both sensitivity to stress and susceptibility to expressing a particular behaviour associated stereotypic behaviour. Leuscher *et al.* (1991) concluded that horses are more likely to exhibit the same stereotypic behaviour if they are related. Genetic predisposition would explain why certain horses develop stereotypies while others kept in the same environment and managed the same did not.

Kiley–Worthington (1983) suggests that stereotypes are more prevalent in Thoroughbreds and Arab-type horses, which adds to the argument for genetic pre-disposition.

Behavioural deprivation is a central issue in animal welfare (Rushen *et al.*, 1993). The term “behavioural need” implies a strong internally driven motivation to perform behaviour (Dawkins, 1983). Hughes and Duncan (1988) state that where there is insufficient negative feedback from the functional consequences of the feeding behaviour, these appetitive sequences will persist, developing into a stereotypic behaviour.

Rees (1984) states that certain behaviours can be copied, and that horses, especially bored ones tend to pick up habits from each other. Stereotypic behaviours cause problems for owners and managers who believe that behaviours can be learned and can harm the horse. This has resulted in the development of many preventative strategies. Anti-weaving bars, electrification of cribbing surface, hanging of obstacles in stable door to prevent weaving, tying up and obstructing the path of box-walkers and many more methods have evolved over time. These attempts to prevent unwanted behaviours become a welfare concern if the behaviour constitutes a coping response. McBride & Cuddeford (2001) measured cortisol levels in horses with stereotypes when devices which physically prevent the performance of the stereotype were implemented. They found significant increases in blood cortisol levels when stereotypies were prevented thereby placing the horses in continual stress. Table 1.6 shows a variety of other management changes that have been introduced in an attempt to control unwanted equine behaviours.

Table 2.6 *Management changes for the control of equine stereotypic behaviour and their reported success (McBride & Long, 2001)*

Technique	Reported prevalence of technique (%)	Proportion reporting success (%)
Reduced time in stable	49.3	75.1
Stable toys	12.3	44.7
Increased exercise	1.4	100.0
Regular change of horses stable	9.6	70.1
Increased social contact	9.6	70.1
Exercise before other horses	5.5	100.0
Feed before other horses	4.1	100.0
Increased hay ration	6.8	60.3
More varied view from stable	2.7	50.0
Use of stable chain instead of solid door	1.4	100.0
Increased size of stable	5.5	100.0

2.7.3 Types of stereotypic behaviours

Although many of these behaviours have been mentioned briefly in the previous sections, this section highlights each specifically, and illustrates the importance of feeding strategies and management over the incidence of these kinds of behaviours.

2.7.3.1 Rapid feed intake

Horses which exhibit this behaviour often do not thrive despite an adequate diet. These horses are more prone to colic, choke, diarrhoea, low-grade founder and foot soreness due to hindgut overload of grain because they eat too quickly allowing a large proportion of whole grain to pass undigested into the manure (Kohnke, 1998). This disorder can be the result of irregular feeding times and long intervals between meals. According to Kohnke (1998) smaller feeds given more frequently and on a regular basis will reduce the risk of digestive disturbance. Feeding hay 30-minutes before giving the ration fills the gut and reduces hunger and helps avoid grain overload. A trainer (2004, G. Werner, Pers. Comm.) at the Ashburton Thoroughbred race training centre suggested placing one or two large rocks in the feed dish so that the horse has to pick around the rocks to get to the feed.

2.7.3.2 Crib-biting

This is a common trait in stabled horses fed mainly on concentrate diets (Jackson *et al.*, 1984). It describes the technique developed by a horse where it bites onto a fixed object with its incisors, arches its neck and gulps in air, making a characteristic grunting sound as the air is swallowed (Nicol, 2000). Crib-biting leads to excessive wear on the horse's incisor teeth (Kohnke, 1998). Crib-biting or wood chewing increases during wet or cold weather (Jackson *et al.*, 1984). Observations by Kohnke (1998) indicate that a stabled horse will spend an average of eight minutes per day chewing stable fixtures. Feeding low fibre diets increases the incidence of wood chewing (Jackson *et al.*, 1984; Nicol, 2000). When diets low in fibre are fed, less chewing is required to consume the meal, leaving more leisure time for the horse to become bored between feeds (Nicol, 2000). Providing good quality hay between meals and at night can reduce boredom. Increasing the bulk of the ration and in turn increasing feeding time has reduced wood biting in stabled horses. Krzak *et al.* (1991) found that horses chewed wood more frequently at times of the day when there was the least activity in the yard. This adds to the boredom theory. Nicol (1999) suggested that horses that crib bite may actually depend on the physical flushing by saliva associated with their crib-biting behaviour. In a trial done by McGreevy and Nicol (1998b), it was found that when hay was restricted together with crib-biting restrictions the horses that would normally crib-bite showed

a significant increase in gut transit time, which was not observed in non-cribbing horses. Nicol (2000) suggests that crib-biting may function to reduce the acidity of the digestive tract in horses on high concentrate diets. Nicol (2000) explains that although the exact mechanism in the horses body by which crib-biting would reduce acidity is unknown, crib-biting itself may result in increased saliva production and increased buffering of the gut.

2.7.3.3 Wind-sucking

This term wind-sucking involves opening the mouth, contracting the pharyngeal muscles, flexing the neck muscles and swallowing air, it is almost identical to crib-biting but the horse achieves the same posture without grasping a fixed object (Nicol, 2000). Both wind sucking and crib-biting result in a pleasurable sensation due to an endorphin release and the expansion of the stomach which makes the horse feel satisfied (Winskill *et al.*, 1995). Swallowing air can lead to digestive disorders and poor condition as the horse can often favour wind-sucking over eating (Kohnke, 1998). This condition has been found to be a result of boredom and frustration in stable confined horses (Winskill *et al.*, 1995). Horses and foals can learn the technique from other horses. By putting mirrors in a windsucker's stable a reduction in the incidence of such behaviour has been achieved (Winskill *et al.*, 1995; Nicol, 1999). There are no completely effective ways of curing wind-sucking in horses (Krzak *et al.*, 1991). In a study investigating the effects of different diets on the frequency of cribbing behaviour, feeding grain and sweetened grain rations caused a significant increase in cribbing activity (Gillham *et al.*, 1994; Winskill *et al.*, 1995). This is thought to be due to the palatability of the rations used which cause β -endorphins to be released in the horse which in turn is thought to enhance stereotypic behaviour (Winskill *et al.*, 1995).

2.7.3.4 Eating bedding

Eating bedding can lead to intestinal compaction, possible poisoning and increased risk of worm egg and larval uptake (Kohnke, 1998). Build up of sand in the narrow bends of the large intestine can lead to sand impaction, colic and fatal bowel rupture (Hayes, 1994; Kohnke, 1998). Horses should be provided with good quality roughage, which takes time to eat and digest and therefore reduce time spent with nothing to do in the stable (McGreevy *et al.*, 1995a).

2.7.3.5 Weaving and stall walking

These can both be described as locomotory activities, which have become fixations (Winskill *et al.*, 1995).

Weaving is believed to be the result of boredom and involves the horse continuously rocking its head and neck from side to side while shifting its weight from one foreleg to the other (Nicol, 2000). Weaving usually occurs while the horse is standing with its head over the stable door, although it can be performed in any part of the stable, or by a field gate (Nicol, 2000). In severe cases, weaving can result in loss of weight (Kohnke, 1998). Weaving is almost impossible to cure (McBride, 1996). Prevention and control involves keeping the horse occupied or putting physical barriers such as bars in the area where weaving occurs. In a trial done by McBride (1996), he tested the success of using such preventative methods and discovered that he could not reduce the occurrence of weaving by using anti-weaving bars.

Stall walking involves the horse walking constantly around the stable (McGreevy *et al.*, 1995a). This activity uses up large amounts of energy and can lead to weight loss (Houpt, 1986). Providing frequent small meals and regular exercise will help to keep these horses busy and hopefully reduce their desire to weave. According to Houpt (1986), many stable vices including stall walking and weaving can be eliminated by pasturing rather than stabling of horses.

2.8 FACTORS AFFECTING DIGESTION AND RATES OF PASSAGE

Feeding frequency and exercise intensity were two main influential factors analysed in chapters two and three of this dissertation. There were other factors that were found to increase or decrease rates of passage and affect digestion, such as feed type (Kohnke, 1998), proportion of hay to concentrate in the ration (Cuddeford *et al.*, 1995) and health of the horse itself (Hayes, 1994; Kohnke, 1998). A review by Van Weyenberg *et al.*, (2006) includes gestation, lactation, work, type of diet and feeding level. The effect of different feed types and feed ingredients were discussed in Sections 1.4 and 1.5. Roughages (Section 1.5.3) were shown to increase absorption through the reduction of digesta flow rate through the GIT (Willard *et al.*, 1977). Roughages increase the mean retention time of feeds within the GIT (Lindsay, 2005). Digestibility is the product of the retention time and the degradation characteristics the feed (Forbes, 1996). Diets high in concentrate (Section 1.5.1) led to rapid rates of passage through the GIT (Willard *et al.*, 1977) and minimal mean retention time. This leads to digestive disorders due to the changes in pH which result from a grain overload in the caecum (Willard *et al.*, 1977; Bailey *et al.*, 2002).

2.8.1 Feeding frequency

Horses are creatures of habit and routine (Kohnke, 1998). Literature has shown that horses fed meals at regular intervals have increased digestive efficiency (Lewis, 1995). This is due to the fact that horses have small stomachs, the capacity of which is only 8-10% of its total digestive tract volume (Krzak *et al.*, 1991) compared to 60-70% for cattle. According to Lewis (1995), horses will naturally eat hourly during the day and every 2 to 3 hours during the night. The size of the meal consumed will have a direct influence over the change that meal has in the horse's body (Lewis, 1995). In other words horses can be fed a grain meal twice a day if the size of the meal is no more than 0.8 - 0.9kg per 100kg body weight per feeding (Lewis, 1995). However to prevent digestive disorders, grain intake in a horse fed only two meals a day should be limited to 0.5kg/100kg per feeding (Lewis, 1995). When grain feeding exceeds these recommended levels, there is a dramatic increase in the amount of starch that escapes digestion and absorption in the small intestine and carries over into the hind-gut. The bacteria in the hind gut use the starch from the grains and produce lactic acid (Bailey *et al.*, 2002). These results in the pH of the hind gut changing to the detriment of the useful fibre-digesting bacteria that die and release harmful toxins (Bailey *et al.*, 2002). Figure 1.3 (Willard, 1975 in Reynolds 2004) shows the difference between the pH changes after a meal between horses fed forage only diets and horses fed concentrates.

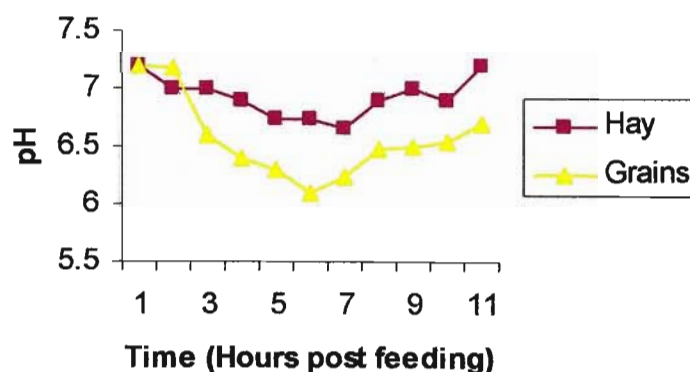


Figure 2.3 Graph showing the changes in caecal pH in horses when fed hay and grain rations (Willard (1975) in Reynolds, 2004).

In an experiment done by Gill and Lawrence (1997) they tested the hypothesis that increased feeding frequency will improve nutrient digestion on Shetland ponies. The results for this trial indicate that there is no significant increase in digestion with an increase in feeding frequency. They did however record large fluctuations in plasma protein concentration that indicates that

water balance is affected by large, infrequent meals. This finding is contrary to what Lewis (1995) found and highlights the importance of further research in this area of horse nutrition.

2.8.2 Exercise intensity

From previous results it is not clear whether exercise affects digestibility in horses. Olsson & Ruudvere (1995) suggested that digestion may be affected in horses in work in such a way that it is improved by light exercise and inhibited by heavy work. Orton *et al.* (1985) reported an increase in apparent digestibility with an increase in exercise. Pagan *et al.* (1998) found exercise to have a small but significant negative effect on dry matter digestibility. They also found that exercised horses consumed more water than when not exercising, suggesting that water intake was the reason for the increased rate of passage seen in exercising horses.

Kohnke (1998) stated that exercise duration and exercise frequency influences a horse's appetite and digestive efficiency. Kohnke (1998) expands by saying that light exercise improved the appetite and digestibility of the feed by increasing the horse's desire to eat to maintain its physical and psychological well being, and balance out its blood sugar levels. Light exercise also reduces rate of passage through the gut and allows increased time for digestion.

2.9 IN VITRO GAS PRODUCTION TECHNIQUE

There is a widespread use of grains as the main source of energy in concentrates in racehorse food worldwide (Kohnke, 1998). As discussed earlier grains used in excess can result in the development of both stereotypic behaviours (Gillham *et al.*, 1994; Winkill *et al.*, 1995) and physiological disorders (Hussein *et al.*, 2004). Feed analysis is important for nutritionally characterizing feeds so that rations can be effectively formulated to optimise animal production (Adesogan, 2002) and in the case of the racehorse, performance.

Micro-organisms in the caecum and colon of the horse break the chemical bonds between individual monosaccharides and use them as food. Fermentability is an indicator of the ease at which this happens and depends in part on the length of fermentation time. *In vivo* this is related to the time the digesta spends in the gut (Campbell *et al.*, 2002). Short chain fatty acids, which are the end products of fermentation, are used as energy sources. To maximise the digestion and absorption of these fatty acids, horses have adaptations to slow down the rate at which digesta moves through the gut (Campbell *et al.*, 2002). Soluble fibres are those fibres that are rapidly and

completely fermented. They are soluble in water and have a branching structure. Insoluble fibres are more slowly and less completely fermented due to their insolubility in water. Cellulose and hemi-cellulose are examples of insoluble carbohydrates (Campbell *et al.*, 2002). Insoluble carbohydrates constitute the structural component of plants (Viljee *et al.*, 1989) and the roughage portion of the horses nutritional regime that is responsible for slowing down rates of passage in the GIT (Kohnke, 1998).

All fermentation results in the production and release of gasses. Different feeds and feedstuffs will cause different amounts of gas production. Fakhri *et al.* (1998) found that the volume of gas produced during an *in vitro* fermentation procedure was a reflection of the amount of carbohydrate fermented. Highly fermentable carbohydrates produce more gas during fermentation than less soluble carbohydrates. However, when comparing feeds of similar digestibility, the feed with a lower gas production, may have a higher nutritive value as more of its degraded fraction is likely to be partitioned to microbial biomass rather than fermentation acids and gas. Gas is a nutritionally wasteful product and excessive gas production in the caecum leads to discomfort and irritability in the horse (Kohnke, 1998).

The *in vitro* gas production technique has been developed over many years as a means of predicting fermentability of ruminant feedstuffs (Rymer, 1999). Lindsay (2005) looked extensively into manipulating the current protocols for ruminant digestibility studies for use in horse research. There are many different methods of determining fermentation *in vitro* (Rymer, 1999). Among the most practical and tested methods of measuring gas production is the method (See appendix 1.1) described by Tilley & Terry (1963). Tilley & Terry (1963) developed their method to measure *in vitro* digestion in ruminants. Unlike other techniques, which only simulate microbial digestion, the method by Tilley & Terry (1963) also mimics gastric digestion and can therefore more accurately predict the *in vivo* digestibility of many forages (Rymer, 1999). In this method the feed sample is initially digested under conditions simulating rumen fermentation, followed by an acid pepsin digestion to solubilize the protein in the feed sample. Lindsay (2005) altered this method to mimic the digestive system of the horse rather than a ruminant. This involved changing the procedure such that acid-pepsin digestion occurred first and microbial fermentation was the final step (Lindsay, 2005).

The gas production technique provides a measure of the proportion of the feed that is fermented (Rymer, 1999). Accurate gauging of the pH and fermentation changes in the hindgut of horses on high grain diets will help toward providing an objective means of explaining the behaviour of the

horse. The *in vitro* gas production technique generates kinetic data and measures the appearance of fermentation gases notably CO₂, CH₄ and H₂ (Adesogan, 2002).

The inoculum that is used is the single greatest source of variation in this technique (Rymer, 1999). Rymer (1999) states that the rumen fluid is highly variable and that significant differences have been recorded between animals, days, and the time of day that rumen fluid is collected. It is therefore essential in trials that utilize rumen fluid to collect at the same time daily from the same animals before the morning feed (Rymer, 1999).

Lindsay (2005) showed that rumen fluid taken from fistulated cows was satisfactory to be used as inoculum when looking at *in vitro* digestibilities of horse feeds. Lindsay (2005) reported no significant differences in the DE, CP, GE, DM, CF, ADF and NDF when comparing inoculum obtained from horse faeces and inoculum obtained from rumen fluid.

In a trial by Murray *et al.* (2003), faecal inoculum collected from ponies fed diets with varying levels of starch had little effect on the results of the *in vitro* digestibility study. Mathematical analysis of the gas curves produced showed no effect of donor animal on the rate or extent to which the feed substrates were degraded. However, the feedstuffs that were analysed in the trial by Murray *et al.* (2003) showed significant differences in their individual fermentabilities. Three substrates were used, a grass hay, a low starch concentrate and a high starch concentrate. There was no difference between the total gas volume produced between the hay and the low starch concentrate but significantly more gas was produced when the high starch concentrate was fermented. Other sources of inoculum include caecal fluid, effluent from a Rusitec, faeces and frozen or freeze dried rumen fluid. The use of pure bacteria cultures in the future may increase the reproducibility of the technique and reduce the reliance on surgically modified animals (Rymer, 1999).

The *in vitro* technique has many advantages over *in vivo* or *in situ* methods. *In vitro* techniques are simple, inexpensive and require standard laboratory equipment. It requires only a small quantity of test feed and it can be used as a rapid screening or indexing technique for a large number of forage samples (Schneider & Flatt, 1975).

2.10 FACTORS AFFECTING THE GAS PRODUCTION PROFILE

2.10.1 Effect of venting gas during the incubation

The gas that is produced during an *in vitro* fermentation needs to be released from solution if it is to be detected (Rymer, 1999). When the partial pressure of a gas is reduced through venting a gas bottle, the solubility of the gas in the culture medium rapidly decreases. This can be seen by the effervescence that is produced. Theodorou *et al.* (1998) states that less gas will be produced in systems where gas is not vented. However, the precise effect of not venting gas during incubation is still unclear (Rymer, 1999). According to Rymer (1999), allowing pressure to accumulate during incubation can affect the gas production profile. This can be avoided through venting gas (Theodorou *et al.*, 1994) or by increasing the volume of the fermentation vessel (Schofield & Pell, 1995).

2.10.2 Effect of agitation on the sample

Wilkins (1974) observed no effect of agitation on the lag time, but did observe that the rate of gas production was increased by shaking the bottles. Stevenson *et al.* (1997) did not show any effect of shaking on the pattern of fermentation or on biomass yield. However Pell & Schofield (1993) observed that the coefficient of variation in the gas production profile was increased if the medium was not agitated. It was suggested that this was because the carbon dioxide tended to form supersaturated solutions if it was not shaken or stirred. In a study reported by Rymer *et al.* (1998), the volume of gas produced was increased by 58% when shaking speed was increased from 0 to 45 oscillations per minute. There was no further increase in gas production when the shaking speed was increased to 60 oscillations per minute. Results indicate that there is a definite effect of shaking on gas production profiles when using an automated pressure transducer. However, subsequent trials showed that shaking had little to no effect when incubating with a manual pressure transducer (Rymer, 1999).

2.10.3 Effect of sample size and preparation

Theodorou *et al.* (1994) noticed a linear increase in the total gas volume with increase in the amount of substrate used. The rate of gas production was not affected. Care must be taken to ensure that the system is capable of buffering acid produced, and that accumulated pressure is not too

great as to affect the pattern of gas evolution when using large sample sizes. Very small sample sizes increase risk of experimental error.

The gas production technique was developed using dried, ground samples of feed. This destroys the physical structure of the feed, and according to Rymer (1999) will almost certainly alter its gas production profile. The optimum feed particle size is unknown; however in the *in vivo* situation feed would be ground by chewing. Feed samples *in vitro* cannot be reduced in this way but should undergo some sort of processing before hand (Rymer, 1999).

2.10.4 Effect of quantity, source and preparation of inoculum

Increasing the proportion of rumen fluid in the inoculum solution has been observed to increase the volume of gas produced (Wood *et al.*, 1998), increase the rate of gas production and decrease the observed lag time (Pell & Schofield, 1993). It is very important to ensure that the microbial activity of inoculate is relatively constant between experiments and that initial microbial activity is measured (Rymer, 1999). Gas produced by microbes alone can be ascertained through blanks. Cone *et al.* (1996) observed that the rate of fermentation increased when the rumen fluid sample was taken after the morning feed, but total gas volume was not affected.

It was observed by Trei *et al.* (1970) that the volume of gas produced was greater when rumen fluid was taken from steers fed grain rather than hay. Cone *et al.* (1996) observed a similar result, and they concluded that the gas production profile brought about by changes in the ration of the donor animal were small. Rymer (1999) states that previous data indicates that for animals in similar physiological states, end point measurements are not strongly affected by donor species. He does however conclude in saying that there is evidence to suggest that the kinetics of fermentation will be different.

Straining of the inoculum is important as mixing rumen solids with samples results in decreased lag times and increased rate of fermentation (Mertens & Weimer, 1998). However removing micro-organisms from the rumen and then subjecting them to straining are traumatic events for micro-organisms (Rymer, 1999) and for this reason microbial cultures should perhaps be given time to recover by pre-incubating with a basal mixture for 24-hours before use (Harris, 1996).

2.10.5 Faeces as alternate source of inoculum

The use of faeces as inoculum was suggested to overcome the need to maintain surgically modified animals, but the effect of the donor animal's diet might still have an effect (Rymer, 1999). The microbial population of the faeces of ruminants is dissimilar to the microbial population in the rumen, due to the influence of gastric digestion and the contribution of the caecum to the microbial population (Kohnke, 1998). However Nsahlai and Umunna (1996) found that when comparing reconstituted sheep faeces as a source of inoculum to rumen fluid, the faeces underestimated rates of gas production and *in vitro* dry matter digestibility up until 48-hours of incubation when the microbial population has successfully established itself in the sample. They suggested that this occurred due to the initial microbial mass in the faeces being lower than that of the rumen fluid. After 48-hours of incubation these differences became insignificant suggesting that faeces may replace rumen fluid and perhaps caecal fluid when incubations extend to or beyond 48-hours. Due to the fact that horses are hindgut fermenters (Kohnke, 1998) and the microbial population of the faeces differs very little to that in the caecum it would be possible to use hindgut fermenters faeces as a replacement for caecal fluid (Lowman *et al.*, 1996). Murray *et al.*, (2003) found that faecal inoculum was a suitable replacement for caecal fluid and this trial was successful in estimating *in vitro* digestibility of horse feeds.

2.10.6 The use of 'Blanks'

Blanks are used to correct for changes in atmospheric pressure (Pell & Schofield, 1993). They are also used to correct for residual fermentable organic matter that is included in the inoculum (Pell & Schofield, 1993). The blank incubation provides confirmation of the activity of the initial inoculum (Rymer, 1999).

2.11 DISCUSSION

Starch found in grains is a common ingredient in all horse feed available on the market today. The horse is a non-ruminant herbivore having high rates of caecum and colonic fermentation. Grain overload, from high levels of particularly maize in the feeds, can cause distinct physiological disturbances, metabolic disorders and undesirable stereotypic behaviours.

It is not enough to feed the right amount of food. Horses in the wild eat small amounts continuously throughout the day and most of the night. For horses confined to stables for most of

the day and night it becomes important for feed to be given at the right frequency throughout the day. By feeding less concentrate the time interval required between feeding and exercise is reduced which could improve management efficiency. The effects of feeding frequency on behaviour and vices could be a fundamental step towards improved performance. A trial that compares different feeding frequencies would be a crucial step towards deciding what the ideal feeding frequency is. However it must be remembered that racehorse yards in South Africa rely heavily on labour and it is not always practical to have a strategy of feeding more than four times per day.

The effect on exercise levels and frequency on the behaviour of Thoroughbred racehorses is very important. Exercise not only prepares the horses for future events but also acts to make them tired and hence less bored in the stables and therefore less inclined to perform stereotypic behaviours. A comparison between horses being fed the same meal at the same frequency but with differing exercise intensities and frequencies would be beneficial in determining the extent to which exercise affects stereotypic behaviours.

The roughage-concentrate ratio of a horse in hard training as said by the NRC (1989) must be adhered to (40:60). Feeding too little roughage has been connected to the development of stereotypies and feeding too much concentrate would not supply the horse with enough energy to perform to their maximum. Feeding too high levels of concentrate will have behavioural and physiological repercussions. Due to the rapid fermentation of starch under conditions of grain overload in the caecum, gas production is increased and gut motility is decreased resulting in a distension of the hind gut and a higher incidence of colic and laminitis. Large amounts of lactate produced by bacteria during grain overload irritate the gut lining and decrease the pH of the hindgut. These changes have been shown to significantly decrease forage nutrient utilization because of the damage to useful fibre digesting bacteria through dramatic reduction in pH. *In vitro* trial work looking at a grain, at different ratios to roughage, and the consequences thereof on fermentation and pH changes in the caecum would be beneficial in determining the extent to which grain can physiologically affect the horse.

The need to gallop faster and further than ever before has put pressure on the horse industry to determine which management strategies are the most beneficial for Thoroughbred racehorses. This dissertation aims to highlight various management strategies and their successes and failures. The *in vitro* study delves into a relatively unexplored area of horse nutrition and hopes to highlight to the reader the connection between highly fermentable carbohydrates and various problems experienced within the typical Thoroughbred racehorse yard.

CHAPTER THREE

3 COMPARING THE EFFECTS OF NUTRITIONAL MANAGEMENT ON THE TIME BUDGETING OF THOROUGHBRED RACEHORSES FROM TWO DIFFERENT TRAINING YARDS

3.1 INTRODUCTION

Domestication of the horse has led to a dramatic change in the natural lifestyle and feeding habits of the horse. The restricted environment created by stabling horses often has a significant effect on their normal time budgets as horses can no longer spend the majority of their day foraging and expending energy looking for suitable resources (Winskill *et al.*, 1995). This has led to the suggestion that frustration of specific motivational systems may underlie stereotypic behaviour (Rushen *et al.*, 1993). Many common problems associated with feeding are the result of boredom and confinement (Houpt, 1986), irregular feeding times, restriction of social interaction at feed times (Nicol, 2000), the feeding of highly concentrated rations (Nicol, 2000) that are quickly consumed, inadequate roughage (Marsden, 1993) and lack of opportunity for self exercise or regular exercising (McGreevy *et al.*, 1995a; Kohnke, 1998).

The horse is a trickle feeder by nature (Hodges and Pilliner, 1991; Kohnke, 1998) and is a highly sociable creature (McGreevy *et al.*, 1995a). The Thoroughbred race horse however is confined to a stable for up to 20 hours a day and fed a diet high in grains (McGreevy *et al.*, 1995a). Feeding a concentrated feed in this manner eliminates additional time that confined animals can occupy themselves with ingestion and manipulation of food (Winskill *et al.*, 1995) causing both behavioural and physiological problems. The typical confined Thoroughbred horse is provided with a balanced diet, roughage and water, but no stimulation or visual and physical social contact (McGreevy *et al.*, 1995a).

McGreevy *et al.*, (1995b) discovered that one of the management factors associated with a high incidence of stereotypic behaviours in stabled horses was stable designs that minimized contact between neighbouring horses. Horses have a well defined social structure, and the high turnover rate of horses in racing yards and the lack of interaction could be a major contributor to the occurrence of aggressive behaviour as a means of venting this frustration. According to Mills & Nankervis (1991), aggression in stabled horses is higher than that observed in the wild.

Marsden (1993) found that feeding practices had a greater effect on the incidence of abnormal behaviours than housing design. In a study done by McGreevy *et al.* (1995a), it was found that offering roughage at frequent intervals could reduce the incidence of stereotypic behaviours in a racehorse yard. Cuddeford (1996) found that as long as horses have a constant supply of roughage their feeding behaviour, even when confined to a stall, would be very similar to that demonstrated by a grazing horse. However the racehorse is an athlete with a reduced roughage intake to compensate for the bulk high energy concentrate intake (Kohnke, 1998), the time it would like to spend eating roughage is reduced and the incidence of behavioural disorders and vices consequently increases (McGreevy *et al.*, 1995b).

Behaviour and temperament problems associated with the oestrous cycle are common. Many mares and fillies become extremely difficult when they are “in season” or “on heat” (Rees, 1984). Some commonly observed signs associated with the oestrous cycle may include: aggression, kicking, increased interest in other horses especially colts and geldings, decreased cooperation, decreased concentration, nervousness and unpredictability (Rees, 1984).

Excess dietary grains fermenting in the horse’s hindgut can lead to irritability and an increase in stereotypic behaviour (Kohnke, 1998). According to Kohnke (1998), giving a horse smaller feeds more frequently and on a regular basis will reduce the risk of digestive disorders and reduce the frequency of much stereotypic behaviour. As with all animals, there is variation in the response of individual horses to particular feeding regimes (Pearce, 1975). Excess energy will make a horse more difficult to handle and control when riding (Kohnke, 1998). Large amounts of grain in diets such as these racehorse diets will ferment in the hind gut, increasing the hind gut acidity level which in turn has been known to increase the incidence of stereotypic behaviour (Winskill *et al.*, 1995).

In similar trials, suggestions have been made that an increase in exercise reduces the time a horse would spend crib-biting (Krzak *et al.*, 1990). Some stereotypes can be learned (Kiley-Worthington, 1983) and an increase in feeding frequency reduces stereotypic behaviours (McGreevy *et al.*, 1995a).

The trial reported here was designed to investigate the effects of the amount of time spent in training, feeding frequency and sex of horse on stereotypic behaviour, using horses on intense and moderate level training days, two different feeding frequencies (two vs. four times per day) and fillies and geldings.

3.2 MATERIALS AND METHODS

Forty Thoroughbred horses from two training establishments were observed for 96 hours, over four consecutive 24-hour periods, with behaviours noted every 10 minutes. This provided a total of 576 observations to analyse. Trial work was conducted in winter and all horses were in training as competitive racehorses. Animals were between the ages of three and five years, and between 150cm and 170cm at the withers in height. The trial was conducted at the Ashburton Training Centre in Ashburton, near Pietermaritzburg, KwaZulu-Natal. Horses from Yard two were weighed. Horses from Yard one were difficult to handle and proved impossible to weigh on the digital scale at the training establishment. Girth and length from point of shoulder to point of buttock was measured to determine calculated body weight (using Equation 2.2 (Huntington, 1991) that is repeated below) to provide all horses with a body weight measurement.

$$\text{Body weight (kg)} = \frac{\text{Heart Girth}^2 \text{ (cm)} \times \text{Body Length (cm)}}{11,880}$$

A regression co-efficient was obtained in Microsoft Excel (2005) from calculated and actual body weights to determine accuracy of the Equation 2.2 (Huntington, 1991).

Thirteen fillies and seven geldings were looked at from yard one and ten fillies and ten geldings were looked at from yard two.

Daily concentrate and hay rations, orts and faeces were collected and weighed. In yard one horse were fed twice a day and in yard two, horses were fed four times a day. Yard one fed only a commercially produced meal, 160g crude protein (CP)/kg, while Yard two fed the same brand of meal of the same CP content to 12 horses and a mixture of this meal and another brand (160g CP/kg) cubes to eight of the horses. *Eragrostis curvula* was fed *ad libitum* to all the horses. Cubes in the mixed rations made up only 14-15% of the ration. Cubes are usually included at levels of 50% and more (Kohnke, 1998). The trainer used the 15% inclusion of cubes as a method of sustaining ingestion rates in selective eaters (2004, G. Werner, Pers. Comm.). Cubing of feeds has been found to increase rate of ingestion and reduce selectivity of ingredients, but can also increase the chances of choke if the horses don't chew their feed properly (Gallagher and Corn, 1997).

Apparent digestion coefficients (DC) were calculated using Equation 3.1 described by Schneider & Flatt (1975), and did not take into account any nutrients of endogenous origin. DC were calculated for entire rations using the digestibility by difference method, to determine the percentage of nutrients that did not appear in the faeces.

Equation 3.1 DC =

$$\frac{[\text{Wt nutrient in hay (g)} + \text{Wt nutrient in concentrate (g)}] - \text{Wt nutrient in faeces (g)} \times 100}{\text{Wt nutrient in hay (g)} + \text{Wt nutrient in concentrate (g)}}$$

The trial began at 03h00 on a Monday morning and ended at 03h00 on a Friday morning, with the horses' behaviours being recorded at ten-minute intervals throughout the trial period. Horses were observed for a minimum of 10 seconds and behaviours that occurred outside the observation period were not included. The behaviours specifically noted were; eating hay, eating concentrate, eating bedding, aggression, banging stable door, weaving, bucking, nodding, wind-sucking, crib-biting, walking around for more than three seconds or pacing, pushing bedding around with nose, lying down, standing and resting and standing alert (adapted from Sweeting *et al.*, 1984). These particular behaviours were chosen because after observing the horses during a trial observation period prior to the start of this specific trial, these were the normal and abnormal behaviours most specifically observed. In addition, exercise intensity was noted, Tuesday and Thursday being gallop days (intense exercise level) and Monday and Wednesday were canter and trotting days (moderate exercise level).

All feeds and faeces were analysed. DM and ash were determined according to AOAC (1995), method 930.15 and method 942.05 respectively. Nitrogen was analysed in a LECO FP 2000 Nitrogen Analyser using the Dumas Combustion method 990.03 (AOAC, 1995). Fat (ether extract) was extracted according to the Soxhlett procedure using a Buchi 810 Soxhlett Fat extractor (Buchi Laboratories-Technik AG, Switzerland). Faeces samples collected were subject to a proximate analysis (AOAC, 1995) to determine their nutrient content. Faecal weights were determined as they occurred, noting the frequency of defecation, and samples for a horse were pooled over the four days and a 10% sample was retained for further analysis.

Data analysis was conducted using Genstat V6.2 (2002). General analysis of variance was used with feeding frequency and exercise level as treatments except in the analysis of behavioural data where feeding frequency, exercise and sex of the horse were treatments.

3.3 RESULTS AND DISCUSSION

The body weights of horses were similar between exercise intensities and between sexes ($P>0.05$). The mean body weight of the male and female horses weighed was the same ($439.2\pm8.1\text{kg}$) A regression of actual body weights against body weights calculated using Equation 2.2, showed a high correlation ($r=0.81$) between the calculated and actual values (Figure 2.1). This indicates that for Thoroughbred horses between 380kg – 580kg live weight, the Equation 2.2 by Huntington (1991) is a useful estimate of actual bodyweight.

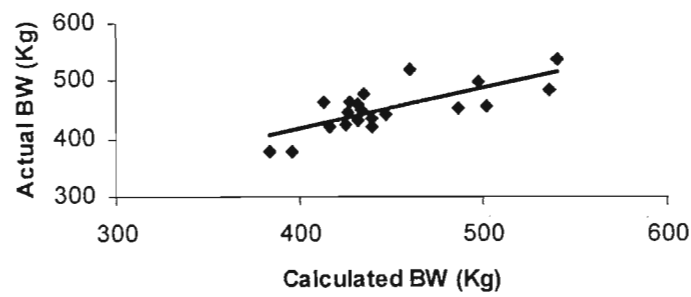


Figure 3.1 Regression between actual and calculated body weights ($r = 0.81$) of Thoroughbred racehorses

The feed analysis (Table 2.1) showed discrepancies in the advertised CP content (16% CP) of the cube ration (160g/kg) when compared to that obtained through the analysis. There was no significant difference observed between the nutrient compositions of the meal feed and the feed where cubes were added.

Table 3.1 Nutrient compositions of meal, cubes, mix offered of 15% cubes and 85% meal and roughage provided to Thoroughbred racehorses in training (All results described on a dry matter (DM) basis)

Feed type	Meal	Cubes	Meal/Cube mix	<i>Eragrostis curvula</i>
Crude protein (g/kg)	166.1	145.9	163.0	73.9
Calcium (g/kg)	13.2	13.4	13.2	3.1
Phosphorus (g/kg)	3.5	4.4	3.6	1.1
Fat (g/kg)	28.8	13.4	26.5	8.8
Moisture (g/kg)	157.6	133.3	153.4	115.8
GE (MJ/kg)	18.12	17.73	18.06	17.93
NDF (g/kg)	285.7	274.7	284.1	808.1
ADF (g/kg)	128.2	110.3	125.5	447.3
Crude fibre (g/kg)	85.2	68.4	82.7	394.1
Lysine (g/kg)	5.3	4.1	5.1	*

The nutrient composition of the faecal samples is described in Table 2.2. No significant differences in the nutrient compositions of the faecal samples were obtained between the feeding frequencies ($P < 0.05$).

Table 3.2 *Nutrient composition of faecal samples collected from Thoroughbred racehorses in training receiving two and four meals a day (Results described on DM basis)*

Nutrients	Feeding frequency	
	Twice daily	Four times daily
Crude Protein(g/kg)	138.9	136.7
Calcium (g/kg)	13.4	14.1
Phosphorus (g/kg)	7.5	8.3
Fat (g/kg)	54.9	56.4
Moisture (g/kg)	748.3	756.5
GE (MJ/kg)	19.20	19.32
NDF (g/kg)	663.5	674.4
ADF (g/kg)	437.1	407.6
Crude fibre (g/kg)	293.9	298.4

The horses in Yard one that fed twice a day ate more hay per day than the horses in Yard two that were fed four times per day ($P < 0.001$) (Table 2.3). Horses in Yard two ate more concentrate than horses in Yard one ($P < 0.05$). Horses in Yard one spent less time eating both hay and concentrate than horses in Yard two (Table 2.3). On days when the exercise level was intense, the horses in both yards consumed more hay than when exercise levels were moderate ($P < 0.05$). This increase in hay consumed is corroborated by an increase in time spent eating hay on those days (Table 2.7). The increase in exercise would have led to an increase in energy requirements and appetite on those days. The amount of concentrate consumed did not differ between exercise intensities because the concentrate levels were controlled by the trainer. It is plausible that if the concentrate given had been greater in quantity, the horses intakes may have been higher as orts collected were minimal. Hay intake was *ad libitum*.

The hay: concentrate ratio for horses in training should be approximately 40:60 (NRC, 1989; Kohnke, 1998). The ratio for Yard one was approximately 28:72 and the ratio for Yard two was

approximately 22:78 (Table 2.3). Both of these ratios, although significantly different from each other ($P<0.001$), are more importantly significantly different from the required ratio. To increase the roughage proportion of the diet the trainer could include additional roughage such as lucerne, which is also highly palatable, into the concentrate portion of the ration. This would also act to slow down rate of ingestion (Lewis, 1995) and occupy the horses during the night until the meal was finished which could in turn reduce the incidence of stereotypic behaviours (Krzak *et al.*, 1991).

Horses in race-training should consume a total dry feed weight of 2.5% of their body weight per day (Kohnke, 1998). The average weight of the horses in this trial was 439 ± 8.1 kg. Therefore, these horses should have been consuming approximately 10.98kg dry feed per day. The total dry feed intake for Yard one and two were 9.14 ± 0.089 kg and 9.16 ± 0.089 kg per day, respectively. These horses were therefore eating slightly below their capacity. The trainers could afford to increase the quantity of hay these horses were eating. According to Lewis (1995), horses can be fed a concentrate meal containing a high level of grain twice daily if the size of the meal is no greater the 0.8kg or 0.9kg feed to 100kg body weight per feeding. This works out to 3.6kg per meal for a 450kg horse. The horses being fed twice a day are receiving on average 3.3 ± 0.28 kg concentrate at each meal. They are therefore eating within the limits described by Lewis (1995).

When intakes were expressed as a percentage of body weight there was no difference between either the feeding frequencies or exercise levels.

Table 3.3 Hay and concentrate intakes (kg/d); Hay:Concentrate (H:C) ratios and intake as a percentage (%) of body weight (BW) averaged over the trial period between Thoroughbred racehorses fed at different feeding frequencies and at different exercise levels

Yard	Exercise level	Feeding frequency Meals/day	Hay intake kg/day	Conc. intake kg/day	H:C ratio	Total intake as % of BW
1	Moderate	2	2.25 ^b	6.57 ^b	0.35 ^a	2.04
	Intense	2	2.77 ^a	6.69 ^b	0.41 ^a	2.18
Mean		2	2.51	6.63	0.39	2.11
2	Moderate	4	2.05 ^b	7.31 ^a	0.28 ^b	2.17
	Intense	4	2.07 ^b	6.92 ^b	0.30 ^b	2.07
Mean		4	2.06	7.12	0.28	2.12
Overall mean			2.29	6.87	0.33	2.11
s.e.d.			0.18	0.28	0.04	0.09
l.s.d. (5%)			0.26	0.39	0.05	0.13

^{a,b} Means in same column bearing different superscripts differ significantly.

s.e.d = standard error of difference, l.s.d = least significant difference

Apparent digestibility coefficients were calculated using the digestibility by difference method, Equation 6 (Schneider & Flatt, 1975), for each nutrient in the feed. As faecal samples were pooled over the four day trial period, the effect of exercise level on the apparent digestibility coefficients could not be established. However, the apparent digestion coefficients for horses in each yard over the experimental period could be determined (Table 2.4). Thoroughbred racehorses should receive a diet with a DE of approximately 11-13 MJ/kg feed (NRC, 1989). The data showed that the rations had an average digestibility of 72.3% and an energy content of 12.50 MJ DE/kg DM feed offered. This is not in excess of what they should have been receiving, which suggests the vices noted during this trial were not due to excess energy in the rations but rather a function of feeding management. The DC of fat is interesting and can be explored in further work, particularly pertaining to glycaemic issues in the horse, with meal sizes and frequency necessarily interfering with the time available for substrate utilization in the small intestine (Ellis & Hill, 2005)

Table 3.4 *Digestion coefficients of rations fed during the trial period to Thoroughbred racehorses eating twice and four times daily*

Feeding frequency	Crude protein	Crude fibre	Fat	NDF	ADF	GE
Twice daily	67.14	66.79 ^a	20.25	71.24 ^a	66.60 ^a	72.29
Four times daily	66.38	62.80 ^b	20.49	68.81 ^b	64.05 ^b	72.36
Mean	66.97	64.79	20.31	70.69	66.03	72.31
s.e.d	1.319	0.687	2.022	0.781	0.697	0.066
l.s.d. (5%)	2.607	1.324	4.000	1.543	1.377	0.131

^{a,b} Means in same column bearing different superscripts differ significantly.

s.e.d = standard error of difference, l.s.d = least significant difference

Defecation frequency was higher ($P<0.05$) on days of intense exercise, and horses fed four times a day defecated more frequently ($P<0.01$) than horses fed twice a day (Table 2.5). Exercise has been shown to increase rates of passage of digesta through the gut (Orton *et al.*, 1985). Increasing feeding frequency mimics the horse’s natural feeding habit of continuous flow through the G.I.T. Previous research has shown that an almost continuous supply of food should be available to stabled horses (Kohnke, 1998). Smaller more frequent meals will increase the rate of passage of digesta and reduce time available for stereotypies to develop. Pagan *et al.* (1998) found that exercised horses consumed more ($P<0.05$) water than non-exercised horses, and suggested that it could be the increased water intake that affected the rate of passage and not the exercise itself.

Faecal weight was different ($P<0.05$) between feeding frequencies. Horses that were fed four times a day, produced greater weights of faeces per day than horses fed twice-daily. This can be explained partially by the fact that horses fed four times per day also consumed significantly more concentrate on a daily basis (Table 2.3) than horses fed twice daily which were consuming slightly more hay. Hay will slow down the rates of passage of the concentrate fed to the horse and thereby slow down defecation frequency and reduce faecal weights (Willard *et al.*, 1997).

Table 3.5 Defaecation frequencies and faecal weights (kg) observed per day in Thoroughbred racehorses fed at two feeding frequencies and at two exercise levels

Yard	Exercise level	Feeding frequency	Defecation frequency/day	Faecal as is weight/day (kg)
1	Moderate	2	5.65 ^b	5.07 ^{bc}
	Intense	2	6.89 ^a	5.51 ^{ab}
	Mean	2	6.27	5.29
2	Moderate	4	7.25 ^a	6.05 ^a
	Intense	4	7.52 ^a	6.21 ^a
	Mean	4	7.38	6.13
	Overall mean		6.82	5.71
s.e.d.			0.52	0.46
l.s.d. (5%)			1.04	0.90

^{a,b} Means in same column bearing different superscripts differ significantly at the 5% level.

s.e.d = standard error of difference, l.s.d = least significant difference

Table 2.6 shows the time spent by the horses in stereotypic behaviours. Stereotypic behaviours are repetitive invariant behaviours with no obvious goal or function (Mason, 1991). Behaviour was recorded in 10-minute intervals during this study. Results are shown as number of incidences of each behaviour observed at 10-minute intervals over a 24-hour period (Table 2.6). The abnormal behaviours that were observed were; nodding, licking walls/stable surfaces, pushing bedding around with nose, eating bedding, wind-sucking, crib-biting and pacing.

Feeding frequency had the most significant impact on the time spent in a stereotypic activity ($P<0.001$) (Table 2.6). Horses eating only twice a day spent on average 86.6 minutes more per day involved in vice-like behaviour than horses fed four times a day. Exercise intensity showed no significant effect on any stereotypic behaviour evaluated in this trial.

There were no significant differences between feeding frequency and exercise intensity with respect to aggression, banging stable doors, bucking or pawing. There were no interactions found between feeding frequency, exercise intensity and sex.

Nodding ($P<0.01$), licking stable surfaces ($P<0.001$), pushing bedding around with nose ($P<0.05$) and eating bedding ($P<0.001$) were shown to occur more frequently in horses being fed twice a day. Although exercise intensity was not a significant factor, nodding is believed to be related to locomotion (Kiley-Worthington, 1983). The results of this trial, however, suggested that nodding was also a feeding-related stereotype. Eating bedding, pushing bedding around with nose and licking surfaces are all believed to be foraging or eating stereotypes in origin (Kiley-Worthington; 1983). Results from this trial concur with that statement as it was the horses which were eating less and hence spending less time eating (i.e. the horses in the yard that fed twice a day) that were more inclined to perform these particular stereotypes.

Wind-sucking ($P<0.01$), crib-biting ($P<0.05$) and pacing ($P<0.05$) occurred more often in fillies than in geldings. Geldings are castrated male horses and therefore have less hormonal activity than fillies. The trial yards had colts (entire males), whose presence can stimulate oestrous in fillies - which in turn will affect their behaviour (Rees, 1984). Fillies and mares in oestrous often compete below their expected level and become difficult to ride and handle, this is an indication that they are irritated and frustrated and hence more likely to perform stereotypies as a means of release (Leuscher *et al.*, 1991). Companion animals such as sheep appear to reduce the frequency of action in horses with severe weaving and pacing stereotypes (McBride & Cuddeford, 2001). Stable toys designed for horses alleviate boredom and mirrors can be hung in stables where the managers consider the vice to have developed through a desire for increased social interaction (McAfee *et al.*, 2002). Contrary to expectation, wind-sucking ($P<0.01$) and crib-biting ($P<0.01$) were more common in the yard that feeds four times per day. It was expected that horses fed more frequently through out the day would wind-suck and crib-bite less frequently (McGreevy *et al.*, 1995). Although the possibility exists that this yard accidentally bought in many horses with the same stereotypic problems, the data lead to the suggestion that vices like crib-biting and wind-sucking are learned behaviours. Kiley-Worthington (1983) proposed that some stereotypes could sometimes be learned by imitation although usually it occurs from mare to foal. Cooper and Nicol (1993) and McGreevy *et al.* (1995b) both suggested that animals may be more likely to develop stereotypies if their neighbours already perform them. This is a controversial idea and more research is required before it can be completely confirmed, but it is an interesting possibility and would help in the explanation of many stereotypic behaviour cases.

Table 3.6 *Treatment effects on mean values of all significant stereotypic behaviours observed in Thoroughbred racehorses fed twice and four times daily, with two different levels of exercise intensity and between the sexes*

	Behaviour x10 min	Total vices	Nodding	Licking	Push with nose	Eat bedding	Wind- sucking	Crib- biting	Pacing
Feeding frequency	2	13.91 ^a	1.00 ^a	1.91 ^a	0.51 ^a	8.01 ^a	0.04 ^b	0.43 ^b	1.10
	4	5.25 ^b	0.36 ^b	0.86 ^b	0.23 ^b	0.12 ^b	0.75 ^a	1.02 ^a	0.91
	Means	9.58	0.67	1.39	0.37	4.07	0.39	0.73	1.01
	s.e.d.	1.08	0.20	0.23	0.11	0.84	0.24	0.19	0.20
	l.s.d. (5%)	2.07	0.39	0.46	0.23	1.65	0.47	0.38	0.39
Exercise intensity	Moderate	9.48	0.67	1.40	0.42	4.26	0.30	0.69	1.05
	Intense	9.68	0.67	1.37	0.33	3.87	0.49	0.75	0.96
	Means	9.58	0.67	1.39	0.75	4.07	0.40	0.72	1.01
	s.e.d.	1.08	0.20	0.23	0.11	0.84	0.24	0.19	0.20
	l.s.d. (5%)	2.07	0.39	0.46	0.23	1.65	0.47	0.38	0.39
Sex	Fillies	9.80	0.61	1.31	0.36	3.89	0.59 ^a	0.91 ^a	1.18 ^a
	Geldings	9.18	0.80	1.52	0.39	4.39	0.04 ^b	0.39 ^b	0.68 ^b
	Means	9.49	0.71	1.42	0.38	4.14	0.32	0.65	0.93
	s.e.d.	1.1	0.21	0.25	0.12	0.88	0.25	0.20	0.21
	l.s.d. (5%)	2.17	0.41	0.48	0.24	1.73	0.50	0.40	0.41

^{a,b} Means in same column bearing different superscripts differ significantly at the 5% level.

s.e.d = standard error of difference, l.s.d = least significant difference

Standing alert (Table 2.7) decreased ($P<0.001$) when exercise was increased, which could be due to the horses being more tired. Standing alert also decreased ($P<0.001$) when feeding frequency was increased. By increasing feeding frequency the time allowable for all other activities is reduced because the horses will spend more time eating. An interaction between feeding frequency and sex ($P<0.05$) was also found. This analysis shows that geldings eating twice a day spent approximately 10.8-minutes more a day being alert than geldings eating four times a day. Also, fillies eating twice a day spent approximately 66.9 minutes more a day being alert than fillies eating four times a day. This indicates that both fillies and geldings are more alert when fed only twice a day, but fillies are more sensitive than geldings to being fed less frequently. Again this could be attributed to the fact that fillies have more hormones affecting their behaviour patterns (Rees, 1984) than geldings do. The time spent standing and resting was not significantly different between the two yards, as was the time spent exercising.

Time spent lying down was not significantly affected by exercise intensity or by the sex of the horse. It was however affected by feeding frequency ($P<0.05$). Horses that were fed four times a day lay down for significantly more time than horses fed only twice daily. Feeding large meals infrequently causes an increase in hindgut acid levels that makes the horses 'nervy' and 'hot' (Kohnke, 1998). Such horses will be agitated and tense and hence less likely to lie down and relax.

Time spent eating concentrate was highly significantly different ($P<0.001$) between feeding frequencies. Horses eating four times a day spent 29.2 minutes more per day eating concentrate than horses fed twice a day, the latter possibly being bored and spending more time in stereotypic behaviour rather than eating. Horses eating four times a day spent more ($P<0.001$) time eating hay than horses fed twice a day.

Horses spent significantly ($P<0.05$) more time eating hay on days of intense exercise than on moderate exercise days. Horses were possibly hungrier on those days because of the increased energy demand that occurs with an increase in exercise intensity and because hay was offered *ad libitum* it was easier for the horses to self-regulate their intake. Conceivably, if concentrate had been offered *ad libitum* the horses would also have eaten more concentrate on days of intense exercise.

Fillies were found to spend on average 22.2 minutes more ($P<0.05$) per day eating hay than did the geldings. This was an interesting yet hard to explain phenomenon. Future studies looking more in

detail into only the differences between the sexes will yield highly interesting and scientifically beneficial results.

Table 3.7 *Significance of expected behaviours in Thoroughbred racehorses being fed twice and four times daily, with two different exercise intensities and between fillies and geldings*

	Behaviour X 10 min	Standing alert	Lying down	Eating ration	Eating hay
Feeding frequency	2	31.78 ^a	14.64 ^b	17.01 ^b	17.66 ^b
	4	27.15 ^b	17.45 ^a	19.93 ^a	25.22 ^a
	Mean	29.47	16.05	18.47	21.44
	s.e.d.	1.16	1.10	0.89	0.98
	l.s.d. (5%)	2.29	2.17	1.75	1.93
Exercise intensity	Moderate	32.30 ^a	15.44	18.17	20.32 ^b
	Intense	26.63 ^b	16.65	18.77	22.56 ^a
	Mean	29.47	16.05	18.47	21.44
	s.e.d.	1.16	1.1	0.89	0.98
	l.s.d. (5%)	2.29	2.17	1.75	1.933
Sex	Fillies	28.81	15.95	18.43	22.22 ^a
	Geldings	30.68	16.21	18.55	20.00 ^b
	Mean	29.75	16.08	18.49	21.11
	s.e.d.	1.21	1.15	0.93	1.03
	l.s.d. (5%)	2.40	2.28	1.84	2.03

^{a,b} Means in same column bearing different superscripts differ significantly at the 5% level.
s.e.d = standard error of difference, l.s.d = least significant difference

Horses that spend most of their days and nights confined to stables are more likely to develop stereotypies than horses that are free to forage. This trial aimed to ascertain which factors involved in management predisposed horses to stable vices. It becomes difficult to determine exactly which management factors are responsible for the development of a stereotype. Stereotypic behaviours are not according to Rees (1984) caused by one factor, they are rather a result of genetics, past experiences as well as present circumstance. This trial aimed to highlight some of the main present circumstances involved in creating an environment where horses tend to develop stereotypies.

3.4 CONCLUSIONS

As energy expenditure was not determined it is difficult to accurately say whether the horses received more energy (DE/kg in the feed) than what was required. However, the energy consumed and digested by the horses involved in this trial was not greater than the NRC (1989) requirement for Thoroughbred races horses in work. Thus we can deduce that in this instance it was not an energy overload from the feed that made the horses tend toward stereotypic behaviours.

The high grain rations may have resulted in increased fermentation in the hindgut that causes gas and irritates the horse, and increases caecal acidity (Rowe *et al.*, 1995). Nicol (1999) discusses the idea that wood chewing is an attempt by the horse to raise gastric pH. Future trials will have to establish the degree to which hindgut acidity is actually a problem and which feed constituents are most to blame. Most research done expresses the need for smaller, more frequent meals to reduce the chances of caecal acidosis and the possible ensuing behavioural problems (McGreevy *et al.*, 1995b). However the ingredients in the feed need to be closely examined to determine the extent to which they could be involved in the development of stereotypies.

Sex of the horses had no influence over their intakes and faecal outputs. Sex did however influence the occurrence of some stereotypes; namely wind-sucking, crib-biting and pacing. Horses are social animals and the lack of social interaction in the training environment must be considered as a frustrating factor to the horses and in particular the fillies in oestrous. It must always be remembered that horses are individuals, with some being more predisposed to behavioural disorders than others. Management strategies need to be implemented to cater specifically for fillies, geldings and colts or management needs to be aware that there are differences between the sexes.

The discrepancy between the observed and advertised protein contents of the cubed feed (Table 2.3) highlights the importance of buying feed from reputable feed companies and the necessity of regular feed analyses to ensure the quality is maintained.

Exercise intensity did not affect observed stereotypies. Horses ate more hay and defecated more frequently on intense exercise days. This is attributed to an increase in appetite and rate of passage of digesta through the GIT. Feeding higher quantities of concentrate at more frequent intervals on days of intense exercise would act to satisfy the horse's appetite and reduce inactive time within the stable. A palatable source of roughage should be incorporated into the meal in addition to the *ad lib*

hay provided. This would slow rate of passage, improve digestion and nutrient absorption and reduce stereotypic behaviours.

Defecation frequency was increased when feeding frequency was increased. This closely mimics the natural state of a horse, where there is a constant flow of digesta through the digestive system. The bulk eaten per day by the horses in this trial was below the horse's capacity. By increasing frequency of meals the potential to meet the horse's capacity is at hand. Horses were less alert and spent more time lying down when feeding frequency was increased, indicating a more relaxed horse that would be less likely to develop a stereotype.

Feeding frequency had the greatest influence on stereotypic behaviour in this trial. Horses eating four times a day showed fewer stereotypies and more 'normal' behaviours than those eating twice-daily. Could this be further improved through feeding six or eight small meals a day? The differences between the yards were highly visible at weighing time when the horses from the yard that feeds twice a day were too naughty to weigh. Was management to blame or was it the different feeding frequencies? Further research could definitely be beneficial to the Thoroughbred racehorse industry in establishing more precisely the management and feeding implications on horse behaviour.

Perhaps the key to a faster racehorse lies in optimizing the horse's welfare and well-being.

CHAPTER FOUR

4 THE EFFECT OF EXERCISE INTENSITY, FEEDING FREQUENCY AND SEX ON TIME BUDGETS OF THOROUGHBRED RACE HORSES

4.1 INTRODUCTION

Krzak *et al.* (1991) suggested that exercise reduces boredom and hence reduces vices such as crib-biting in the stable confined horse. Horses on pasture spend over half their time grazing (Tyler, 1972). Willard *et al.* (1977) reported that feeding a concentrate diet, compared with a hay diet, resulted in a decrease in eating time from 40 to 3.4% of the day. The additional free time resulting from the reduction in time spent eating could lead to boredom (Krzak *et al.*, 1991) and the preparatory conditions for stereotypic behaviour. Confinement, some particular frustration or unpredictability in the environment can cause stress that leads to stereotypic behaviour as a coping mechanism (Mason, 1991).

Fillies and stallions often exhibit undesirable sex related behaviours (Rees, 1984). No stallions were looked at in this trial, but differences between fillies and geldings were observed and noted with respect to behaviour, feed intakes and faecal outputs.

This trial takes a closer look at the relationship between exercise intensity and feeding frequency and how they together affect behaviour. Only one yard was looked at in this trial in an attempt to reduce variations in management that occur between training yards. Krzak *et al.* (1991), believes that exercise reduces wood chewing through a reduction of boredom. This study was conducted to see if changes in intensity of exercise had an effect on the occurrence of stereotypies. From Chapter two it has already been shown that feeding horses four times as opposed to twice a day reduces the incidence of unwanted behaviours. However in this chapter the reduction of feeding frequency occurs in conjunction with a reduction in exercise. This management strategy is examined to see if it has an effect on stereotypies. The influence of sex of the horses on the occurrence of stereotypies was also examined.

4.2 MATERIALS AND METHODS

Twenty Thoroughbred horses from one training establishment were observed over two four day periods. Ten fillies and ten geldings were observed. Trial work was conducted in winter and all horses were in training as competitive racehorses. Animals were between the ages of three and five years, and between 150 and 170 cm in height. The trial was conducted at the Ashburton Training Centre in Ashburton, near Pietermaritzburg, KwaZulu-Natal.

Horses were weighed. Girth and length from point of shoulder to point of buttock was measured to determine calculated body weight using Equation 2.2 (Huntington, 1991). A regression was obtained (Figure 3.1) from calculated and actual body weights to determine accuracy of Equation 2.2 (Huntington, 1991) repeated below.

$$\text{Body weight (kg)} = \frac{\text{Heart Girth}^2 \text{ (cm)} \times \text{Body Length (cm)}}{11,880}$$

Daily concentrate, hay rations and orts were collected and weighed. Horses were fed four times a day except on a Wednesday when they were fed three times a day. Horses were exercised twice a day except on a Wednesday when they were only worked once. Exercise intensity was noted with Tuesday and Thursday being gallop days (intense exercise level), Monday and Wednesday being canter and trotting days (moderate exercise level).

Horses were fed mixtures of 16% commercially produced cubes, 16% commercially produced meal, maize and lucerne in the concentrate portion and *Eragrostis curvula* was fed *ad libitum* to the horses as their main source of roughage. All feed and hay allocations were weighed and orts collected and weighed to determine the weight of concentrate and roughage ingested per day.

Apparent digestion coefficients (DC) were calculated for entire rations by the digestibility by difference method (Schneider & Flatt, 1975) to determine the percentage of nutrients that did not appear in the faeces. This was done using Equation 3.1 (Schneider & Flatt, 1975) repeated below.

Equation 3.1 DC =

$$\frac{[\text{Wt nutrient in hay (g)} + \text{Wt nutrient in concentrate (g)}] - \text{Wt nutrient in faeces (g)} \times 100}{\text{Wt nutrient in hay (g)} + \text{Wt nutrient in concentrate (g)}}$$

Faecal weights were determined as they occurred, noting the frequency of defecation, and samples for a horse were pooled over the four days and a 10% sample was retained for further analysis.

Faecal samples were subject to a proximate analysis (AOAC, 1995) to determine nutrient composition and apparent digestibility coefficients. Average apparent digestibility coefficients were calculated between fillies and geldings and a mean overall determined.

The trial began at 03h00 on a Monday morning and ended at 03h00 on a Friday morning. Horse behaviours were recorded at ten-minute intervals throughout the trial period. This procedure was repeated the following week using the same experimental horses. The behaviours specifically noted were; eating hay, eating concentrate, eating bedding, aggression, banging stable door, weaving, bucking, nodding, wind-sucking, crib-biting, walking around for more than three seconds, pushing bedding around with nose, lying down, standing and resting and standing alert (Adapted from Sweeting *et al.*, 1984). This adaptation was used as these were the behaviours the horses were observed to execute during a pre-trial observation period.

All feeds and faecal samples were analysed to determine nutrient composition. DM and ash were determined according to AOAC (1995), method 930.15 and method 942.05 respectively. Nitrogen was analysed in a LECO FP 2000 Nitrogen Analyser using the Dumas Combustion method 990.03 (AOAC, 1995). Fat (ether extract) was extracted according to the Soxhlett procedure using a Buchi 810 Soxhlett Fat extractor (Buchi Laboratoriums-Technik AG, Switzerland).

Data analysis was conducted using Genstat V6.2 (2002). Two treatment structures were used in the analysis of the nutrition and faecal data *viz* the sex of the horse (filly or gelding) and the management strategy (intense exercise and four meals a day, or moderate exercise with a reduction in meals per day on the off day). The behaviour data included feeding frequency, exercise intensity and sex as treatments in standard analysis of variance.

4.3 RESULTS AND DISCUSSION

The bodyweights of total horses (fillies and geldings) did not differ between treatments. A regression (Figure 3.1) of bodyweights calculated using Equation 2.2 (Huntington, 1991) against actual bodyweights, showed a high correlation ($r = 0.932$) between calculated and actual values. This demonstrates the reliability of Equation 2.2 (Huntington, 1991) for accurate prediction of bodyweights for Thoroughbred racehorses within 6.72kg of their actual weight. The average weight of horses in this yard was 456.13 ± 6.72 kg.

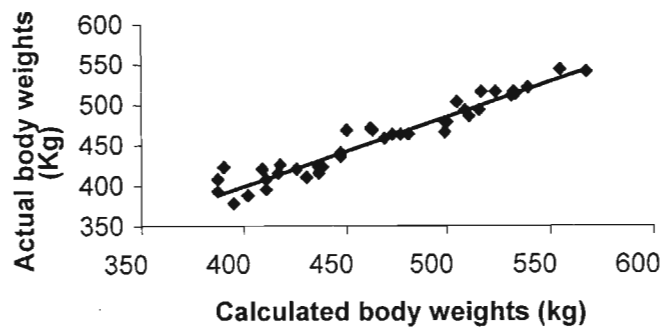


Figure 4.1 Regression between actual and calculated body weights ($r = 0.93$) of Thoroughbred racehorses

The nutrient content of the 16% commercially produced cubes, 16% commercially produced meal, maize, lucerne and *Eragrostis curvula* is reported in Table 3.1.

Table 4.1 Nutrient composition of ration components fed to Thoroughbred racehorses in training fed four times and three times per day (All results on a DM basis)

	16% CP Cubes	16% CP Meal	Maize	Lucerne	<i>Eragrostis curvula</i>
Protein (g/kg)	180.6	158.4	102.7	185.3	32.7
Calcium (g/kg)	19.6	11.9	0.4	15.1	3.1
Phosphorus (g/kg)	6.1	3.9	2.5	2.9	1.1
Fat (g/kg)	34.2	75.0	37.0	14.4	10.5
Ash (g/kg)	80.1	74.6	11.8	87.7	56.1
Moisture (g/kg)	12.4	91.7	117.5	117.5	91.7
NDF (g/kg)	241.6	280.6	236.4	515.8	747.9
ADF (g/kg)	109.3	118.7	39.5	333.7	407.3
Crude Fibre (g/kg)	80.0	88.1	212.0	265.7	309.2
GE (MJ/kg)	17.97	18.83	18.70	18.23	17.93

All feed and hay allocations were weighed and orts collected and weighed to determine the weight of concentrate and roughage ingested per day (Table 3.2)

Table 4.2 *Average daily weights (kg) of feed components in a racehorse ration fed four and three times per day (All results on an as is basis)*

Average	Monday	s.e.d.	Tuesday	s.e.d.	Wednesday	s.e.d.	Thursday	s.e.d
Maize	0.59	0.09	0.59	0.09	0.58	0.11	0.57	0.11
16%CPmeal	2.48	0.15	2.48	0.16	1.45	0.22	2.48	0.15
Lucerne	2.44	0.78	2.83	0.61	1.91	0.31	2.34	0.24
16%CPcubes	4.22	0.14	4.23	0.14	4.23	0.15	4.21	0.19
Total	9.73		10.13		8.17		9.60	

Faecal samples were analysed to determine nutrient composition and calculate apparent digestibility coefficients (Table 3.3).

Table 4.3 *Nutrient analysis of faecal samples collected from Thoroughbred racehorses in training and pooled over the collection period (All results on a DM basis)*

Nutrients	Mean	s.e.d.
Protein (g/kg)	127.5	36.9
Calcium (g/kg)	17.6	1.9
Phosphorus (g/kg)	10.0	2.4
Fat (g/kg)	50.2	11.0
Ash (g/kg)	118.5	35.1
Moisture (g/kg)	751.8	35.3
NDF (g/kg)	657.4	74.6
ADF (g/kg)	416.2	60.3
Crude fibre (g/kg)	305.2	76.1
GE (MJ/kg)	18.73	4.4

Amounts of concentrate eaten (Table 3.4) by the horses were different between the treatments. Concentrate eaten was higher on days when exercise was intense ($P<0.001$) and reduced when exercise was reduced. Fillies were found to consume more concentrate than geldings ($P<0.05$). Fillies in general are more highly strung than geldings due to hormonal cycles (Rees, 1984). Often nervy, highly strung horses will not maintain their body weight even when fed high quality feeds (Kohnke, 1998). The trainer was aware of this and was trying to feed horses accordingly to maintain a body condition ideal for racehorses (2004, C. Naidoo, Pers. Comm.).

Eragrostis curvula (Table 3.4) was consumed *ad libitum* while the horses were stable confined. There were no differences observed between the intakes of hay between the sexes. However, the consequences of reducing exercise intensity was an increase in hay intake ($P<0.05$). This leads to

the suggestion that horses that are not tired from intense work have more time available for eating hay.

Table 4.4 Hay and concentrate intakes (kg/day, as is) and Roughage: Concentrate (R:C) ratios and intakes as a percentage of body weight of Thoroughbred racehorses in training (NRC (1989) described for a 450kg horse).

Exercise level	Sex	<i>Eragrostis curvula</i> intake (kg)	Conc. intake (kg)	R:C ratio	Intake as % BW
Intense	Fillies	2.05	10.02 ^a	0.65	2.65
	Geldings	2.19	9.71 ^a	0.65	2.66
	Mean	2.12	9.87^a	0.65	
Moderate	Fillies	2.62	9.10 ^b	0.70	2.58
	Geldings	2.69	8.80 ^b	0.68	2.56
	Mean	2.66	8.95^b	0.69	
	Overall Mean	2.39	9.41	0.67	2.61
	NRC (1989) requirements	4.50	6.75	0.66	2.50
	s.e.d.	0.31	0.21	0.03	0.11
	l.s.d. (5%)	0.62	0.42	0.07	0.21

^{a,b,c} Means in same column bearing different superscripts differ significantly at the 5% level.

s.e.d = standard error of difference, l.s.d = least significant difference

Roughage: concentrate ratios (Table 3.4) were determined by adding the lucerne in the meal with *Eragrostis curvula* that was fed *ad libitum* to ascertain the total roughage portion of the diet and the concentrate portion was the amount of concentrate fed minus the lucerne portion. On days of moderate exercise the horses were found to consume more hay and hence the ratio between roughage and concentrate differed on those days. However the ratios determined do not differ significantly from the NRC (1989) requirement for horses in training (0.66). The addition of lucerne to the concentrate in this yard has proven to be highly beneficial in maintaining the correct roughage: concentrate ratio. This method of adding roughage such as lucerne into the concentrate portion of the diet could have improved the roughage: concentrate ratio of the horses discussed in Chapter Two.

Intake as a percentage of body weight should be 2.5% for racehorses in training (NRC, 1989; Kohnke, 1998). The average weight of a horse in this yard was 456.13±6.72kg. These horses should therefore be eating 11.40kg feed per day. Feeding above this recommendation would lead to an increase in rate of passage of digesta through the gut and ultimately a waste of digestible nutrients because digesta would move through the system too quickly to get absorbed. The average intake was not found to be different from the NRC (1989) recommendation. On days when exercise intensity was reduced the feed was below the NRC (1989) recommended weight of feed intake but

the requirements of the horse dropped too. This was done intentionally by the trainer to reduce the probability of a physiological disorder, such as azoturia, which is associated with a sudden reduction in exercise without a reduction in feed intake, being induced.

Apparent digestion coefficients for a thoroughbred racehorse involved in this trial are shown in Table 3.5. There was no difference between the apparent digestion coefficients obtained for fillies and geldings. Apparent digestion coefficients could not be compared between the exercise intensities as the data was pooled over the four collection days.

Table 4.5 *Apparent Digestion coefficients of total rations received by Thoroughbred fillies and geldings in training. (Rations are described in Table 3.2).*

	Dry matter	Crude protein	Crude fibre	Fat	NDF	ADF	DE
Fillies	74.12	79.41	39.11	66.60	51.06	39.00	74.28
Geldings	73.25	79.63	39.54	66.82	52.20	34.80	73.34
Overall Mean	73.69	79.52	39.33	66.71	51.63	36.90	73.81
s.e.d.	1.44	1.23	3.45	1.74	2.99	3.59	1.51
l.s.d.5%	2.85	2.44	6.77	3.43	5.88	7.11	2.98

^{a,b} Means in same column bearing different superscripts differ significantly at the 5% level.

* P<0.05; ** P<0.01

s.e.d = standard error of difference, l.s.d = least significant difference

Using Equation 3.1 (Schneider & Flatt, 1975), the mean DE/kg of the rations used in this trial was calculated. The requirement for Thoroughbred racehorses is between 11-13 MJ DE/kg feed given, and the mean DE/kg calculated for all the horses was 13.31. From this it can be assumed that the horses are having their energy requirements met by the rations they are being fed.

Equation 3.1

$$\text{MJ DE/kg} = \frac{(\text{wt hay} \times \text{GE hay}) + (\text{wt conc} \times \text{GE conc}) - (\text{wt faeces} \times \text{GE faeces})}{(\text{wt hay} \times \text{GE hay}) + (\text{wt conc} \times \text{GE conc})} \times 100$$

There was no difference in defecation frequency (Table 3.6) between the sexes of the horses or between the two differing management strategies. The sex of the horse significantly affected the weight of faeces (P<0.05). This is due to the fact that fillies ate more concentrate than geldings.

Table 4.6 Defaecation frequencies and fresh faecal weights (kg) observed per day in racehorses fed according to two different management strategies

Ex level	Sex	Defecation frequency/day	Weight/day (kg/day)
Intense	Fillies	7.50	9.45 ^a
	Geldings	7.35	8.58 ^a
	Mean	7.43	9.02
Moderate	Fillies	7.20	8.99 ^a
	Geldings	7.60	8.29 ^b
	Mean	7.40	8.64
	Overall mean	7.41	8.83
s.e.d.		0.39	0.49
l.s.d. (5%)		0.78	0.98

^{a,b} Means in same column bearing different superscripts differ significantly at the 5% level.

* $P < 0.05$

s.e.d = standard error of difference, l.s.d = least significant difference

Vices only showed significant differences between the sexes (Table 3.7), with fillies licking stable surfaces ($P < 0.001$) and weaving ($P < 0.01$) more than geldings, and geldings spending more time being aggressive ($P < 0.01$) and eating bedding ($P < 0.05$) than fillies. Geldings ate less concentrate than fillies (Table 3.3) so they could have been hungrier and this hunger manifested itself in aggression and bedding eating. According to Winskill *et al.* (1995) horses confined to stables with limited food to satisfy hunger and to occupy their time, are highly likely to show signs of stereotypic behaviours. It is not uncommon for anabolic steroids to be administered to horses in the racing environment. Although it is speculative in this case, it would account for some of the unusual aggressive behaviour observed in many of the geldings. Anabolic steroids are used to increase muscular development in sports horses, and are closely related to the male hormone testosterone. It is testosterone that promotes muscling in stallions and their increased levels of aggressive behaviour (Rees, 1984). Fillies often exhibit stereotypic behaviour associated to the oestrous cycle (Rees, 1984) that can be aggravated by limited direct and social contact (McGreevy *et al.*, 1995b). Bucking, crib-biting, nodding, pawing, pacing and wind-sucking showed no response to any of the treatments.

Total vice like behaviour (Table 3.7) was not significantly affected by treatments. On Wednesdays the horses spend 1.036 ± 0.82 hours (Table 3.8) less out exercising. This indicates that the trainers' method of reducing feed in conjunction with a reduction of exercise on a Wednesday has been successful in reducing the incidence of stereotypes, even though there was a change in routine which usually causes stress to horses which can lead to stereotypic behaviour developing (Kohnke, 1998).

Table 4.7 *Effects of feeding frequency, exercise intensity and sex on the occurrence of stereotypic behaviours in Thoroughbred racehorses (Behaviours were recorded at ten minute intervals for four consecutive 24-hour periods)*

	Behaviour x10 min	Aggression	Weaving	Licking	Eat bedding	Total vices
Feeding Frequency	3	0.25	0.39	0.90	2.61	5.38
	4	0.49	0.53	0.78	2.91	6.38
	Mean	0.37	0.46	0.84	2.76	5.88
	s.e.d.	0.20	0.39	0.23	0.63	0.83
	l.s.d. (5%)	0.40	0.77	0.46	1.24	1.64
Exercise Intensity	Moderate	0.38	0.43	0.84	3.08	6.35
	Intense	0.48	0.56	0.78	2.59	5.91
	Mean	0.43	0.50	0.81	2.84	6.13
	s.e.d.	0.14	0.27	0.17	0.44	0.59
	l.s.d. (5%)	0.28	0.54	0.33	1.238	1.16
Sex of horse	Fillies	0.24 ^b	0.89 ^a	1.09 ^a	2.34 ^b	6.15
	Geldings	0.62 ^a	0.10 ^b	0.52 ^b	3.33 ^a	6.11
	Mean	0.43	0.50	0.81	2.84	6.13
	s.e.d.	0.14	0.27	0.17	0.44	0.59
	l.s.d. (5%)	0.28	0.54	0.33	0.88	1.16
	Overall mean	0.41	0.48	0.82	2.81	6.05

^{a,b} Means in same column bearing different superscripts differ significantly.

s.e.d = standard error of difference, l.s.d = least significant difference

Time spent eating ration and time spent lying down did not differ between treatments. There were no differences between fillies and geldings with respect to any expected behaviours (Table 3.8). Horses spent more time exercising on days of intense exercise than on days of moderate exercise ($P<0.001$). This could be due to the horses going out for work only once on a Wednesday. Horses in general in this trial stood alert for longer periods of time (42 ± 11.22 minutes) on days of moderate exercise ($P<0.001$). However, on Wednesdays when feeding frequency was reduced to three times per day horses spend less time being alert ($P<0.001$) and more time resting ($P<0.001$). This result would have been exactly what the trainer was hoping for on that day. Horses spent more ($P<0.001$) time eating hay on days when feeding frequency was three times per day. This would have been due to the fact that they spent more time confined to their stables on that day.

Table 4.8 *Effect of feeding frequency, exercise intensity and sex on expected behaviours in Thoroughbred racehorses (Behaviours were recorded every 10 minutes for four consecutive 24-hour periods)*

	Behaviour	Exercising (hours)	Standing alert	Standing resting	Eating hay
Feeding frequency	3	0.54 ^b	29.30 ^b	44.84 ^a	20.12 ^a
	4	1.57 ^a	33.62 ^a	36.12 ^b	15.73 ^b
	mean	1.07	31.46	40.48	17.93
	s.e.d.	0.08	1.59	2.34	1.33
	l.s.d.(5%)	0.16	3.14	4.61	2.64
Exercise intensity	Moderate	1.10 ^b	34.64 ^a	36.94	17.57
	Intense	1.53 ^a	30.44 ^b	39.67	16.08
	mean	1.31	32.54	38.31	16.88
	s.e.d.	0.06	1.12	1.65	0.94
	l.s.d.(5%)	0.11	2.22	3.26	1.86
Sex of horse	Fillies	1.31	32.83	37.83	17.20
	Geldings	1.32	32.25	38.78	16.45
	mean	1.31	32.54	76.61	33.65
	Overall mean	1.23	32.18	51.80	22.82
	s.e.d.	0.06	1.12	1.65	0.94
	l.s.d.(5%)	0.11	2.22	3.26	1.86

^{a,b} Means in same column bearing different superscripts differ significantly at the 5% level.

s.e.d = standard error of difference, l.s.d = least significant difference

4.4 CONCLUSIONS

Variation in observed behaviours within one racehorse training establishment was looked at in this trial. This reduced the variation through management that was encountered in Chapter Two. The general management encountered in this yard was exceptional with the manager being present the majority of the time and staff being kind and gentle with the horses. Because of this, any incidence in stereotypic behaviour can be classified as having occurred through the changes in routine, which include changes in exercise intensity and changes in feeding frequency. It must however be remembered that stereotypies are also a result of past experience, genetics and the present circumstances of the horse (Rees, 1984). A trial of this nature is highly informative as it is conducted *in situ*. However, future trial work needs to be conducted in a simulated yard situation to be able to give horse's adequate time to adjust to changes in treatments. This kind of trial unfortunately becomes very expensive to conduct. This trial was not ideally structured being a functioning race training yard, however some useful information was gathered and a lot was learned about the benefits of good management with the funds available.

The reduction in time spent eating concentrate on days when horses were only fed three times, did not lead to an increase in stereotypies as was predicted by Krzak *et al.*, (1991), but rather resulted in an increase in hay intake and time spent resting and a reduction in time spent alert. In this trial there were no differences in observed stereotypies between the management strategies. This is contrary to what was found in Chapter Two of this dissertation but was however expected (Krzak *et al.*, 1991). These results can only be explained by a reduction of energy intake in conjunction with a reduction in exercise on that day. This is a clever management strategy that should be practiced among all training yards.

There were no differences in stereotypic behaviour between exercise intensities within the management strategies. In the author's opinion to successfully analyse the effect of exercise intensity on behaviour, the horses need to be subjected to that exercise program for a longer period of time. Changing the exercise program daily did not give horse's sufficient time to adjust. Responses from the day before may have been carried over and affected the next day's results.

There were no significant differences between fillies and geldings for expected behaviours. However, geldings were found to spend more time eating bedding and showing signs of aggression than fillies and fillies were found to spend more time weaving and licking stable surfaces than geldings. Significant differences between fillies and geldings were expected as there were differences observed in Chapter two. Although the responses in this trial are different, the driving forces behind these behaviours can possibly be attributed to a lack of social interaction and frustrations in the training facility environment as suggested by McBride & Cuddeford (2001).

The lack of significant stereotypies between the different feeding frequencies and between the different levels of exercise intensity indicates a highly successful management strategy. Manipulating feeding frequency as exercise demands change appears to be a successful method of controlling stereotypies in racehorses. Further management strategies could be implemented such as sheep as companion animals (McBride & Cuddeford, 2001), mirrors in the stable and stable toys (McAfee *et al.*, 2002).

Thoroughbred racehorses are bred to make money by running as fast as they can. Owners and trainers would benefit greatly through participating in more trial work – the value of performing a trial in an operational facility can not be emphasised enough – and surveys. Scientists interested in this field have so many avenues to still explore. Is it viable to feed more than four times per day? Should horses be in small pens rather than confined to stables all day? Is the feed itself or rather the

grains in the feed that is causing the animals to perform stereotypies rather than the management? Are the horses getting the correct ratios of concentrate and roughage, and at what ratio does the incidence of stereotypies increase and is there a physiological explanation? All of these factors need to be considered before scientists and equine researchers can make the horse perform to its maximum potential.

CHAPTER FIVE

5 MEASURING GAS PRODUCTION IN A PRESSURE TRANSDUCER USING RUMEN FLUID AS INOCULATE

5.1 INTRODUCTION

Horses are expensive animal athletes with both feeding strategies and the feed itself being major contributors to their success in racing. The impact of feeding on the digestive tract, gut function and on nutrient digestibility needs to be fully understood to optimise the horses' performance. The horse can be described as a monogastric herbivore that is suited to the digestion and utilization of high fibre diets due to continual microbial fermentation primarily within the hindgut (Harris, 2001). It is this process of fermentation that produces gas.

Starch, sugar, fat, vitamins, minerals and approximately half of the feed protein should be digested and absorbed into the bloodstream from the small intestine. The remaining nutrients and plant fibres proceed on to the hindgut where bacteria and micro-organisms continue the digestive process. The hindgut is made up of the caecum and the colon. VFA's are produced as end-products of the digestion of fibre by the bacteria in the hindgut. These VFA's contribute to the energy requirements of horses on total forage diets. When horses are fed forage alone this digestive system works very well. By increasing the energy requirements of the equine athlete through racing, forage diets do not adequately meet the horses' energy requirements any longer. This has led to the use of concentrates containing highly fermentable grains such as maize. Different fibre types ferment differently (Campbell *et al.*, 2002). Soluble fibres such as starch ferment rapidly because of their solubility in water and structural arrangement of the starch itself. Insoluble fibres such as cellulose and hemicellulose both digest more slowly and are less completely fermented due to their insolubility in water.

Grains are high in starch which when fed in large quantities to the horse, cannot be digested and absorbed completely in the foregut so that a significant proportion of the grains pass into the hindgut. The bacteria in the hind gut use the starch and produce lactic acid resulting in the pH of the hindgut changing to the detriment of the useful fibre-digesting bacteria that die and release harmful toxins. The decrease in hindgut pH due to lactic acid build up may increase the likelihood of "hot" or nervous behaviour in many horses (Krzak *et al.*, 1991; Willard *et al.*, 1977).

Feed evaluation procedures can be time-consuming and costly experiments requiring animals and facilities. *In vitro* techniques have been developed to study the fermentation kinetics of animal feedstuffs without harming or disturbing the animal itself and as a method of reducing costs. The *in vitro* gas production technique generates kinetic data and measures the appearance of fermentation gases (Adesogan, 2002). These gases occur naturally as a result of hind gut fermentation in the horse. The problem arises when diets fed to the horse result in more than the usual amount of gas being produced (McGreevy *et al.*, 1995a). Grains have been connected to this problem (Nicol, 1999). This trial aimed to determine to what extent and at what level maize in particular, which is high in starch, would become detrimental to a live horse because of increased gas production levels. This was done through simulating the digestion of feed within the horse in a pressure transducer.

Murray *et al.* (2003) found that the inoculum donor animal does not have to be the same as the animal on trial. Lindsay (2005) found that there were no significant differences between using rumen fluid from fistulated cattle as inoculum or inoculum derived from horse faeces. In the trial by Murray *et al.* (2003) mathematical analysis of the gas curves produced showed no effect of donor animal on the rate or extent to which the feed substrates were degraded. This information was beneficial as there were no fistulated horses at the University of KwaZulu-Natal to use for that purpose. The feedstuffs that were analysed in the trial by Murray *et al.* (2003) showed significant ($P < 0.001$) differences in their individual fermentabilities. Three substrates were used, a grass hay, a low starch concentrate and a high starch concentrate. There was no difference in the total gas volume produced between the hay and the low starch concentrate but significantly ($P < 0.001$) more gas was produced when the high starch concentrate was fermented. This result reiterates the need to try and anticipate the detrimental level of feed ingredients that are high in starch, such as maize, in horse feed.

The trial described in this chapter used a version of the pressure transducer technique of Theodorou *et al.* (1994) which was formulated for ruminants, to record gas production (GP) of different ratios of maize and *Eragrostis curvula* incubated *in vitro*. However as the digestive system of the horse is not the same as that of ruminants, this method was modified at the University of Natal, Pietermaritzburg, so that the acid pepsin digestion occurs first followed by the microbial digestion as would occur in hindgut fermenters such as the horse. This experiment looked at rate of fermentability, asymptotic values and Y-intercepts achieved for each sample as well as true degradability and true digestibility. Horses are monogastrics that use both acid and microbial digestion (in that order) to break down their food. For this reason the differences between using the

modified Tilley & Terry (1963) two stages of digestion (acid digestion and microbial digestion) method of digesting feed samples and using a one-stage method which only uses microbial digestion to digest samples were compared. This was done in order to determine if the two stage technique is necessary or if for laboratory purposes the one stage technique would be enough.

The experimental feed samples were mixed in different proportions (0:100; 20:80; 40:60; 60:40; 80:20; 100:0). This was done to compare the reaction of the gas production to changes in maize concentration in the diet of the horse. Thoroughbred racehorses should be eating a diet that contains no more than 60% concentrate (Kohnke, 1998). After this level they become more prone to digestive disorders and behavioural problems (Krzak *et al.*, 1991) as the literature reviewed has shown.

5.2 MATERIALS AND METHODS

This trial was run at the Feed Analysis Laboratory at the University of KwaZulu-Natal. A pressure transducer (Pienaar, 1994) was used to determine pressure obtained through gas produced by fermentation of the samples *in vitro* and used as an incubator to incubate the different feed treatments using a modified Tilley & Terry (1963) method (See Figure 4.1).

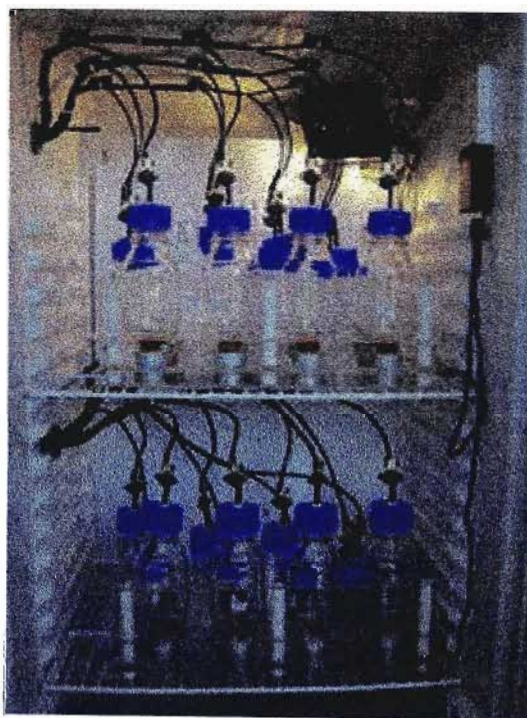


Figure 5.1 Photo showing the actual pressure transducer used in this trial created by Pienaar (1994)

A randomised complete blocks design was used in the analysis of 12 treatments with two replications of each that were randomly allocated to 24 bottles in a modified pressure transducer machine. Measurements of pressure build-up as well as nutrient analysis before and after incubation were done so as to calculate digestibilities and then analysed in Genstat (Version 6.2).

Rumen-fistulated, mature Jersey cows, in good condition served as donor animals for the rumen fluid required for the *in vitro* procedure (Lindsay, 2005). All cows received a hay diet.

Half of the 12 treatments were subjected to two-stage digestion (acid digestion as well as microbial) and the other half were subjected to only microbial digestion. The two-stage method was based on a modified version of the two-stage procedure described by Tilley & Terry (1963), subsequently modified by Minson & McLeod (1972) (Appendix 1.1). The method was modified to mimic the digestive system of the horse with the microbial fermentation following the acid digestion.

Maize and *Eragrostis curvula* samples were milled through a 0.5mm screen. Maize was used because it is a very common grain ingredient in racehorse feeds (Kohnke, 1998). It is an economical and palatable energy source. From previous literature it has been shown to have a fast rate of fermentation (Jackson, 2002) and be connected to behavioural problems (Kohnke, 1998). *Eragrostis curvula* was chosen because it is an economical and commonly used source of roughage. For each experimental run, the treatments were repeated twice and there was a blank included in each experimental run. The experiment ran twice.

Proximate analysis of feeds was done according to the AOAC (1995) (Table 4.1). Neutral detergent fibre (NDF) was determined using the method of Goering & Van Soest (1970) post-digestion to obtain apparent degradability, true degradability and true digestibility. The residue after this trial was very small and was analysed for NDF only. This is sufficient as NDF is the true fibre left after endogenous and microbial proteins have been removed from the sample.

Table 5.1 *Proximate analysis of Maize and Eragrostis curvula used in dilution trial (All results expressed on a DM basis)*

Feed type	Maize	<i>Eragrostis curvula</i>
Crude protein (g/kg)	91.5	54.6
Calcium (g/kg)	0.4	3.1
Phosphorus (g/kg)	2.5	1.1
Fat (g/kg)	37.0	8.8
Moisture (g/kg)	11.8	115.8
GE (MJ/kg)	16.8	17.3
NDF (g/kg)	202.6	797.1
ADF (g/kg)	47.6	452.9
Crude fibre (g/kg)	21.2	394.1

Pressures recorded every 20-minutes over the 72-hour incubation period were analysed. The 72-hour incubation period was chosen because in the pre-trial experimental runs done using the pressure transducer, it was found that the gas stabilized at approximately 72-hours. Pressure was recorded as kilopascals (kPa) and then converted to millilitres (ml) using the calibration shown in Equation 5.1 (Nsahlai and Umunna, 1996)

Equation 5.1 $1\text{kPa} \times 2.2489 = 2.2489\text{ml gas}$

All pressure data was analysed using SAS (1987). Gas production parameters were determined by fitting the following model (Equation 5.2) proposed by Campos *et al.* (2004) to gas production profiles using the NLIN procedure of the SAS (1987) software for a non-linear regression:

Equation 5.2 $y = a / [1 + \exp (2 + 4b (C - t))]$

- Where:
- y = total gas volume (ml) at time t
 - A = the maximum gas volume (ml)
 - t = ∞
 - b = specific degradation rate (maximum rate/maximum volume)
 - C = bacterial colonization or lag time (in hours).

The lag time refers to the time taken (measured in hours) by the microbes in the inoculum to become active and begin fermenting the feed sample and hence begin gas production.

Digestibility refers to the proportion of the ingested feeds or nutrient not excreted in the faeces (McDonald *et al.*, 1995). Apparent digestibility (Equation 5.3) assumes that the faeces are composed entirely of undigested feed substances. In reality part of the faeces consists of micro-organisms and part comes from the body itself (endogenous matter). This is then true digestibility (Equation 5.4). A large difference between apparent and true digestibility indicates a large microbial biomass in the undigested residue (Schneider & Flatt, 1975). To determine true digestibility the neutral detergent fibre (NDF) of the residue needs to be ascertained. The remaining residue left after digestion and removal of supernatant (See appendix 1.1 for procedure) is the true fibre (Schneider & Flatt, 1975).

Equation 5.3

$$\text{Apparent \% DM digestibility} = \frac{[(\text{sample mass} - \text{mass undigested residue}) - \text{mass blank}] \times 100}{\text{sample mass}}$$

Equation 5.4

$$\text{True \% DM digestibility} = \frac{\text{Initial sample mass} - (\text{Total residue fibre} - \text{Blank NDF}) \times 1000}{\text{Initial sample mass}}$$

Degradability and digestibility data was analysed using ANOVA in Genstat V6.2 (2002). Treatment structures included feed (different feed ratios of maize and *Eragrostis curvula*) and stages of digestion (either the microbial only or the one-stage method or the two-stage method which included acid digestion followed by microbial digestion). pH was determined as sample bottles were removed from the incubator before centrifugation.

5.3 RESULTS AND DISCUSSION

Table 4.2 shows the gas production results where non-linear regression in SAS (1987) were used to produce max gas production levels, rates of fermentation and lag times. There were no significant differences between the results for maximum gas production (max gas prod.) between; two consecutive runs, two different methods of digestion or different feed ratios or treatments. This indicates that perhaps the two-stage method suggested by Tilley & Terry (1963) is unnecessary and it would suffice to use only the microbial digestion.

The rates of gas production did not differ significantly (Table 4.2) between the two methods of digestion or between the different treatment feed ratios. The lag times (in hours) did not differ significantly between the two consecutive runs, between the two stages of digestion or between feed treatments (Table 4.2).

The lack of difference between the results achieved from the single and two phase digestion work leads to the suggestion that for this kind of trial the first stage of digestion is not necessary. Further research needs to be conducted to validate this suggestion.

Table 5.2 *Maximum gas produced, rates of gas production and lag times (hours) observed over the 72-hours of incubation between the different feed treatments and between the microbial digestion only (one stage digestion) and the acid digestion and microbial digestion (two stage digestion)*

	<i>Eragrostis curvula</i>	Maize	Max gas produced (ml)	Rate	Lag time (hours)
One stage digestion	0	100	196	0.044	7.85
	20	80	185	0.041	6.41
	40	60	228	0.035	6.08
	60	40	208	0.032	5.58
	80	20	122	0.028	5.85
	100	0	161	0.027	6.62
Means			183	0.035	6.39
Two stage digestion	0	100	170	0.037	6.67
	20	80	251	0.033	5.36
	40	60	166	0.036	4.53
	60	40	196	0.033	6.83
	80	20	174	0.028	4.96
	100	0	152	0.024	7.22
Means			184	0.031	5.93
Overall means			183.5	0.033	6.16
s.e.d.			52.9	0.011	2.81
l.s.d. (5%)			116.5	0.023	6.64

s.e.d = standard error of difference, l.s.d = least significant difference

Degradability (Table 4.3) showed significant differences ($P < 0.001$) between the different feed ratios. Degradability is calculated first from initial crude data. After NDF determination and the removal of the micro-organisms, true digestibility can then be determined. As the proportion of maize in the diet was increased so the feed became more degradable. Degradability is a rough indicator of feed digestibility. Degradability increases as the amount of *Eragrostis curvula* in the ration is decreased. The mixes containing 100 and 80% maize had the highest degradability

($P<0.001$). The mixes containing 100% and 80% *Eragrostis curvula* had the lowest degradability ($P<0.001$) (Figure 4.2).

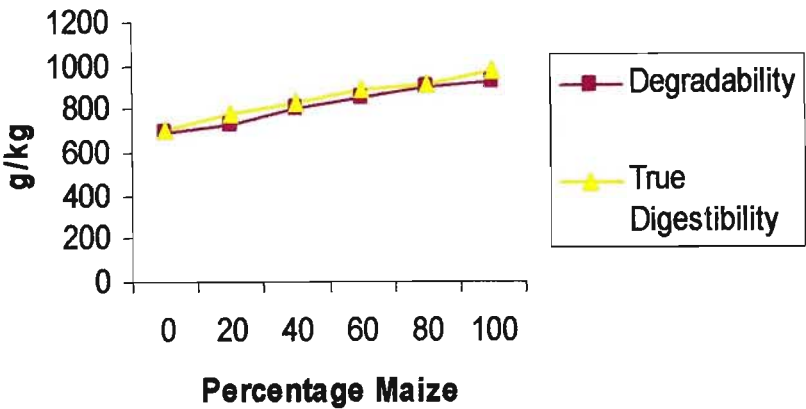


Figure 5.2 Graph showing the behaviour of degradability (g/kg) and true digestibility (g/kg) as the percentage of maize in the mix is increased

True digestibility (Table 4.3) showed significant differences ($P<0.001$) between treatments, which were the different feed ratios. True digestibility increases as the proportion of *Eragrostis* in the ration is decreased and the proportion of maize is increased (Figure 4.2). The lowest level of true digestibility ($702.3 \pm 23.58\text{g/kg}$) occurred with *Eragrostis curvula* hay alone and the highest level of true digestibility ($974.6 \pm 23.58\text{g/kg}$) occurred with maize alone. The differences observed between degradability and true digestibility as seen in Table 4.3 can be accounted for by microbial biomass that attaches itself to feed particles (Schneider & Flatt, 1975).

A linear regression (Equation 5.5) of percentage maize in the mix against true digestibility (g/kg) accounted for 81% of the variation observed. This indicates that the percentage of maize in the ration is a good indicator of true digestibility.

Equation 5.5 $Y = 716.1 \text{ (SE = 11.5)} + 2.61 \text{ (SE = 0.190)} X$
($n = 46$; $r^2 = 0.81$)

Where: Y = true digestibility (g/kg)
 X = mean percentage of maize in the mix.

Table 5.3 Apparent and true degradability and true digestibility results obtained for different *Eragrostis curvula*: maize ratios degraded in vitro

Treatment	<i>Eragrostis curvula</i>	Maize	Degradability (g/kg)	True digestibility (g/kg)
1	0	100	924.6 ^a	974.6 ^a
2	20	80	895.6 ^{ab}	917.7 ^b
3	40	60	855.5 ^b	882.5 ^b
4	60	40	801.4 ^c	826.7 ^c
5	80	20	727.4 ^d	779.8 ^c
6	100	0	696.4 ^d	702.3 ^d
Mean			816.8	847.3
s.e.d.			22.65	23.58
l.s.d. (5%)			46.08	47.92

^{a,b,c,d} Means in same column bearing different superscripts differ significantly at the 5% level.

s.e.d = standard error of difference, l.s.d = least significant difference

There were significant differences ($P < 0.01$) for pH (Table 4.4) between the two methods of digestion. The two-stage method had a significantly lower pH than the one stage method for a majority of the treatments. This could be due to the methodology of this technique (Appendix 1.1). If the digestive acid residues are not removed completely with the supernatant after the first stage of acid digestion, then the pH of the sample will be affected at the end of the microbial digestion phase. This is a complication that is removed when the one stage method is used (only microbial digestion takes place).

There were no significant differences for pH between the different ratios of feed although it was observed that there was a non-significant trend suggesting that as the percentage of maize is increased so the pH decreases (Figure 4.3). Kohnke (1998) stated that when the pH of the hindgut falls below 6.4 the result will be low-grade diarrhoea and cow-pat like droppings. It is this decrease in pH that Willard *et al.* (1977) linked to 'hot' behaviour in horses.

From Table 4.4 it can be seen that in the samples that underwent microbial digestion only, only those with ratios above 60% maize attained a pH below the 6.4 value. This suggests that if animals were eating a mix of maize and *Eragrostis curvula* where maize was included at more than 60% of the mix, these horses would be more likely to exhibit the adverse behaviours and experience physiological problems associated with hindgut acidosis. The samples that underwent the two-stage method of digestion were all below the 6.4 pH value.

Table 5.4 pH measurements obtained after both enzymatic and microbial digestion of feed samples incubated in rumen fluid for 72-hours

	<i>Eragrostis curvula</i>	Maize	pH
One stage digestion	0	100	6.17
	20	80	6.32
	40	60	6.50
	60	40	6.43
	80	20	6.50
	100	0	6.57
Mean			6.42 ^a
Two stage digestion	0	100	6.15
	20	80	6.20
	40	60	6.14
	60	40	6.30
	80	20	6.28
	100	0	6.35
Mean			6.23 ^b
Overall mean			6.33
s.e.d.			0.14
l.s.d. (5%)			0.28

s.e.d = standard error of difference, l.s.d = least significant difference

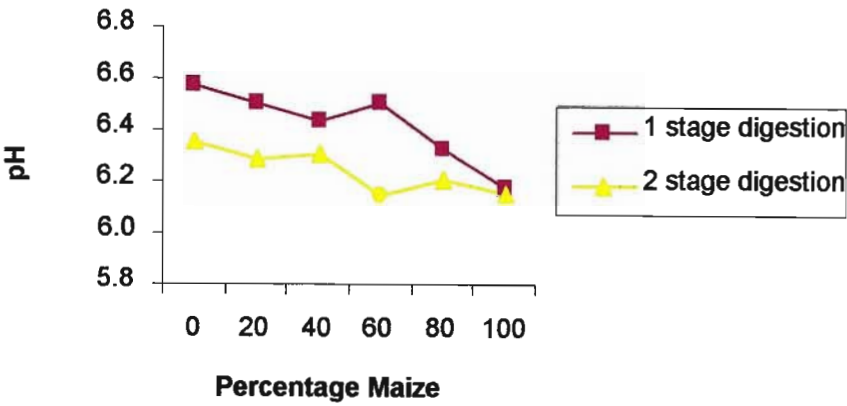


Figure 5.3 Figure showing the apparent trend of pH to decrease as percentage maize is increased

5.4 CONCLUSIONS

It has been shown in literature (Krzak *et al.*, 1991; Nicol, 1999) that diet can significantly influence the behaviour of a horse. High-energy feeds such as maize will make most horses energetic, playful and naughty (Kohnke, 1998). The gas produced from the fermentation of starch in grains causes distension in the hindgut leading to irritation of the horse resulting in these adverse behaviours.

From the results discussed in this chapter it is not possible to objectively say when the percent maize in the diet reaches a level where gas production becomes detrimental. It is clear from the data that digestibility and degradability increases as the level of maize in the diet is increased. This and the fact that maize is a relatively economical ingredient is why maize is fed to equine athletes and reiterates the need to research, find, and use a less fermentable, yet highly digestible alternate energy source. The data also shows that there is a trend evident that demonstrates that as the percentage of maize in the diet is increased so the pH of the hindgut will decrease. Rowe *et al.* (1995) showed that adverse effects such as laminitis and behavioural changes, associated with feeding grain to horses can be overcome by controlling the acidity in the hindgut. A solution to this problem does not necessarily mean the exclusion of maize from rations. Processing of all raw materials but especially maize can improve inclusion levels in rations (McClean *et al.*, 1999) and the use of probiotics has been found to be beneficial in reducing the extent to which the hindgut becomes acidic (Rowe *et al.*, 1995).

This trial was one of the first of its kind done at the University of KwaZulu-Natal, Pietermaritzburg. Future trials I am certain will perfect this method and find conclusive evidence that maize and other highly fermentable feeds are part of the reason for reduced hindgut pH's, laminitis, acidosis and behavioural problems in horses.

CHAPTER SIX

6 GENERAL DISCUSSION AND CONCLUSIONS

6.1 GENERAL DISCUSSION

The motivation for the study sprang from the author's own experience with racehorses and the practical knowledge that some element of racehorse management was affecting them adversely. The aim of the study was to try and isolate the main root factors behind the development of general stereotypic behaviours.

Chapter one looks at previous studies and literature in this area of horse research. This chapter aimed to give a background into horses, feeds and the effect of feeding on the horses' physiology and behaviour. The research showed that there is a link between what is ingested by horses and the behaviour that results (Rowe *et al.*, 1995; Willard *et al.*, 1977). Behaviour studies and surveys done in this field show many stable management strategies that may help in the reduction of stereotypies even before a change in feeding is instituted (McGreevy *et al.*, 1995a). Reducing time spent in the stable (McGreevy *et al.*, 1995a), introduction of stable toys (Henderson & Warren, 2001), increased social contact (Mason, 1993) and increasing stable size (McGreevy *et al.*, 1995a) are just some of the strategies put forward in Chapter one to minimize stereotypic behaviour.

Both studies reported on in Chapters two and three, agree that Equation 2.1 (Huntington, 1991) gives accurate estimates of body weight for Thoroughbred horses between 450kg and 550kg body weight. Practically this equation will be useful when dealing with nervous or difficult horses that don't want to or are unused to getting on the scale such as was experienced during the trial work reported in Chapter two.

The first behaviour study, discussed in Chapter two, showed the importance of regular feed analysis to ensure that feed producers are supplying what their labels advertise (Table 2.1 showed how feed advertised as 160g crude protein/kg was in reality only approximately 146g CP/kg). If this trial were to be repeated, I would suggest the experimenter find subject horses that are all eating the same feed. This was one of the draw backs encountered through working *in situ*.

The sex of the horses was shown to have a significant influence on the manifestation and frequency of stereotypic behaviours. As the vices themselves and the frequency at which they occur were different between the different management systems shown in Chapters two and three, it can be

deduced that management of the different sexes can be important for controlling sex-related behavioural problems. The differences observed between the sexes would make an interesting thesis in itself and future work in this area could greatly change the way fillies, colts and geldings are handled today.

Chapter two shows clearly that feeding frequency has a large effect on the occurrence of unwanted behaviours in racehorses. Future trial work looking at feeding frequency and racehorse behaviour should perhaps look at the effect of feeding up to eight small meals daily as horses have been observed to do in the wild (Davies, 1995). The natural desire of the horse is to eat many small meals throughout the day and a large portion of the night (Kohnke, 1998). A feeding system is required that mimics the natural feeding system of wild horses. This suggestion has many management problems associated with it and would be a highly labour intensive endeavour. A feeder in each stable that distributes small meals at regular intervals would be an ideal, although expensive solution. Chapter three showed no differences in behaviours between feeding frequencies. However this trial only looked at horses within the same yard and on the days when feeding frequency was reduced, there was a simultaneous reduction in energy expenditure for the horses on that day. Future trials looking at the effect of exercise intensity on racehorse behaviour need to allow more time for the horses to adjust to the change in routine so that assumptions made can be more accurate. Again this was a problem associated with working in a functioning racing yard. However, the practical knowledge and insight into racehorses and their behaviour that was gained from being in that environment was invaluable.

A behaviour study in a simulated racehorse yard, rather than a functioning yard, using young Thoroughbred horses, where horses were given sufficient time to adjust to changes in feed and exercise regime, would be a step in the right direction for the accurate analysis of management strategies and feed effects. This was not possible to conduct at Ukulinga research farm at the University of KwaZulu-Natal for financial reasons, but would be the ideal way to research racehorses.

Racehorses eat diets high in grains (Pagan, 1997; Hussein *et al.*, 2004). Chapter four does not show as clearly as had been hoped that high levels of grain cause high levels of gas accumulation in the hind gut and increase the rate of fermentation. However, it clearly shows how increasing inclusion of grains can increase both degradability and digestibility of the meal, and how increasing grains can cause a decrease in caecal pH which has been linked to much adverse behaviour (Willard *et al.*,

1977). This trial was a constructive start toward the goal of analysing the effects of meal feeding high grain diets to working horses.

Pressure transducer trials have many benefits as they can be completed in two or three weeks and do not require horses to be confined to stalls for long periods of time as a typical digestibility trial would. Ideally this work should have been run in conjunction with a live horse digestibility trial so that *in vivo* and *in vitro* results could be compared (Lindsay, 2005). Further research is required to find energy sources other than highly fermentable grains or better ways of processing grains, maize in particular, in the South African racehorse's diet. There are many avenues available for future work in this field. These include testing whether there is conclusively no difference between using rumen fluid or horse faeces as the inoculum and testing the effect of feeding donor animals varying diets and also the effect of taking the inoculum samples at different times of the day. This work needs to be compared to *in vivo* research. Any *in vitro* technique is only of value if it is related to a meaningful *in vivo* measurement (Rymer, 1999). The cost and effort of obtaining reliable *in vivo* data is great, but characterising feeds for which *in vivo* data already exists by the gas production technique would be invaluable.

6.2 CONCLUSIONS

Equine athletes make money (race earnings and resale *inter alia*) but they also cost money! Economically, finding a feeding strategy that will suite the horse's natural behavioural pattern and minimise disturbance of the digestive system would be highly beneficial. When the incidences of metabolic, digestive and behavioural problems are reduced, management will become easier and the equine athlete's performance should be maximized. More research is needed into the effect on desirable and unwanted behaviours of certain feedstuffs, in particular grains, and the timing of feeding on the equine athlete.

To formulate a suitable diet and to develop an appropriate feeding pattern, it is necessary to consider the implications of exercise on energy production and fuel utilization. The digestive physiology of the horse is not designed for large meals two or even three times a day. The behavioural patterns of the feral horse indicate horses naturally prefer to trickle feed. A system where five or six smaller concentrate meals with *ad libitum* hay would be closer to the horse's choice system and would prevent many disorders associated with boredom and digestion. Reducing the concentration of grain as energy in the ration and replacing it rather with vegetable fat (a 'cool' energy source) will reduce excitable energy in the horse, making its periods in the stable more

tolerable and thereby reducing the incidence of behavioural vices. It is also useful to match the work rate of the horses and the concentrate or grain intake. *In vitro* studies are the ideal method of finding alternate energy sources that do not reduce hind-gut pH excessively and limit the production of gases that cause irritation to the horse.

The overall aim of this dissertation was to ascertain whether the behaviour of Thoroughbred racehorses was a side effect of management strategies or a result of the highly fermentable nature of the feed the horses are eating. In the author's opinion it was clearly shown in the research conducted that management has a highly influential part to play in the resulting behaviour manifestations of Thoroughbred racehorses. The impact of the feed on the physiology of the horse was shown by the significant drop in pH observed when high levels of maize were fed. This in itself is an indication of the potential problems through lactic acidosis, laminitis and behavioural manifestations that can be a product of hind-gut acidity. The research conducted showed that both feed and management play extremely important roles in controlling the development of stereotypic behaviour in horses. It would be very difficult and in fact unwise to try and separate the importance of both factors in the welfare and management of racehorses.

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APPENDIX

1.1 PROCEDURE FOR DETERMINING DIGESTIBILITY AND GAS PRODUCTION *IN VITRO* AS DESCRIBED BY TILLEY & TERRY (1963) SUBSEQUENTLY MODIFIED BY MINSON AND MCLEOD (1972).

Reagents

Salivary buffer solution (Mc Dougall, 1948)

Prepare buffers with the following compositions

Buffer A	g/2000ml
Sodium bicarbonate	19.60
Disodium hydrogen phosphate anhydrous	7.40
Potassium chloride	1.14
Magnesium chloride 6-hydrate	0.26
Buffer B	g/100ml
Calcium chloride 2-hydrate	5.3

Immediately before use add 2ml buffer B drop wise to 2000ml buffer A and stir with magnetic hotplate stirrer for 15 minutes while carbon dioxide is bubbled through by means of a gas distributing tube. Place buffer in incubator to maintain a temperature of 39°C.

Stage 1: Rumen Fluid Inoculant

Rumen contents collected by hand from a fistulated cow should be gently squeezed through four layers of gauze. The fluid collected must be drained into a thermos that has been previously rinsed out with hot water and flushed with carbon dioxide to make it anaerobic.

Back in the laboratory, 313ml of strained rumen fluid must immediately be added to 1250ml of the salivary buffer solution, which has been previously warmed to 39°C.

100ml of the buffer rumen fluid mixture must then be added to each bottle containing the feed sample. All feeds to be milled through a 0.5mm sieve and dried for 48-hrs in a force draught oven at 70°C. 1g of feed sample to be weighed into sample bottles and the mass then recorded.

Immediately replace the air above the mixture with carbon dioxide and seal tightly in the pressure transducer for 48-hours at 39°C.

A pressure transducer with a LED (light emitting diode) digital read out meter will be used to measure the accumulation of fermentation gasses in the head space of the culture bottles.

Stage 2: Acid Pepsin Solution

Half fill a 2000ml-graduated Erlenmeyer flask with distilled water, add 15ml concentrated hydrochloric acid and mix well. Add 3g pepsin (activity 1:10 000), make up to the 1500ml mark and dissolve pepsin by stirring on magnetic stirrer. Do not use heat to dissolve.

10 ml of the acid pepsin solution and 0.5ml amylase should now be added to each bottle. Bottles must be closed and then incubated for 48-hrs at 39°C. After 48-hours bottles can be removed and should be allowed to stand for 15 minutes to allow feed particles to settle.

Stage 3: Centrifuge and Analysis

After 48-hours of incubation, remove the bottles from the pressure transducer and measure pH with an electronic pH meter. Centrifuge all bottles for 20 minutes at 18 000G to separate the supernatant. Remove supernatant and dry residue for 48-hours in an oven set at 80°C. Weigh remaining sample and send to laboratory for NDF analysis.