GROWTH, VOLUNTARY FEED INTAKE AND DIGESTIBILITY IN THOROUGHBRED WEANLINGS

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ABSTRACT

This thesis describes two studies evaluating the suitability of an ensiled lucerne and cracked maize feed for consumption by Thoroughbred weanling horses (eight to twelve months of age).

A growth study was conducted to compare the effect of a fibre-based (ensiled lucerne and cracked maize) or concentrate-based supplementary feed (commercial weanling concentrate) on the growth and occurrence of gastric ulceration of Thoroughbred weanling fillies managed under commercial conditions in New Zealand at moderate followed by high feeding levels. During the trial there was an outbreak of strangles (*Streptococcus equi var. equi*) in both groups of horses. Three of the fibre-supplemented and two of the concentrate-supplemented weanlings displayed clinical signs of strangles during the moderate and high supplementary feeding periods, respectively. These weanlings were isolated from their groups for the duration that they displayed clinical signs of strangles.

During the growth trial the weekly body weight gain, wither height and average daily gain (ADG) were not affected by dietary treatment or feeding level. Weekly body weight gain, body condition score and ADG were significantly lower in the weanlings that were infected with *S. equi var. equi* while they were isolated in comparison to the remainder of their group. No association was found between gastric ulceration and dietary treatment.

At the completion of the growth study, a separate voluntary feed intake (VFI) and apparent digestibility study of the ensiled lucerne and cracked maize feed was conducted over a 21 day period using six of the Thoroughbred weanling horses. During this study the duration of total faecal collection required for consistent apparent digestibility measures of dry matter, crude protein and gross energy was determined.

The VFI of the ensiled lucerne and cracked maize feed by the weanling horses (94.57 ±1.43 g DM/kg BW$^{0.75}$) was at the lower end of the range reported by other studies of VFI in young horses fed grass or lucerne hay alone, or in combination with concentrate rations (92.3-134 g DM/kg BW$^{0.75}$). The feed contained 53.96% (±0.72) DM, and 13.22%

(±0.10), CP and 12.47 MJ/kg DM (±0.01) GE on a DM basis. The apparent dry matter (70.55 ±0.40%), crude protein (62.39 ±0.60%) and gross energy (68.51 ±0.43%) digestibility of the feed was similar to other studies of young horses fed lucerne hay and lucerne hay and concentrate diets. There was no significant difference in the duration of total faecal collection on all of the apparent digestibility measures.

The results of this thesis suggest that the ensiled lucerne and cracked maize feed is a suitable alternative to concentrate-based supplementary feeds that are typically fed to grazing weanlings, and that normal growth rates can be achieved by weanlings supplemented with this feed. Additionally, the apparent dry matter, crude protein and gross energy digestibilities of this feed can be accurately measured over a 12 hour total faecal collection.

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LIST OF ABBREVIATIONS

ADG	Average daily gain
BCS	Body condition score
BW	Body weight
CP	Crude protein
DE	Digestible energy
DM	Dry matter
DOD	Developmental orthopaedic disease
EGUC	Equine Gastric Ulcer Council
FF	Fat and fibre rich diet
GE	Gross energy
HCl	Hydrochloric acid
NRC	National Research Council
OC	Osteochondrosis
SS	Sugar and starch rich diet
VFA	Volatile fatty acids
VFI	Voluntary feed intake

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CHAPTER 1

1.1 INTRODUCTION

New Zealand has a reputation for breeding high quality, internationally competitive race horses (Fennessy, 2010). Breeding Thoroughbred horses is an important part of New Zealand's equine industry (Morel *et al.*, 2007; Stowers *et al.*, 2009), and the sale of yearling horses provides a large portion of revenue for breeders (Flores *et al.*, 2011).

The New Zealand equine industry is largely pasture-based due to the mild climate which allows pasture growth throughout the year (Pearce *et al.*, 1998). Because of this, horses are able to obtain a significant portion of their nutrient requirements through pasture (Hoskin and Gee, 2004). While foals can achieve acceptable growth rates when raised on good quality pasture alone (Grace *et al.*, 2003; Brown Douglas *et al.*, 2005), it is common practice to provide supplementary concentrate feed to growing Thoroughbred horses despite the year round availability of pasture (Stowers *et al.*, 2009; Hirst, 2011). This frequently occurs when stud managers are unsure of the extent to which weanlings meet their nutrient requirements through pasture (Stowers *et al.*, 2009; Hirst, 2011).

Nutrition and management practices can have a large influence on the athletic potential of young horses during their first 18 months of life (Staniar *et al.,* 2005). Feeding weanling horses large quantities of concentrate feed to achieve rapid growth rates (Warren *et al.*, 2011), has been implicated in increasing the risk of osteochondrosis (Stromberg, 1979; Jeffcott, 1991), and gastric ulceration (Nadeau and Andrews, 2009).

High fibre diets, particularly lucerne (*Medicago sativa*), can reduce the risk of gastric ulceration (Nadeau *et al.*, 2000; Lybbert *et al.*, 2007), and promote natural feeding behaviours (Hill, 2007). Lucerne hay, also known as alfalfa, is a popular forage for feeding horses (NRC, 1989; Small, 1996; Crozier *et al.*, 1997), has a higher nutritive value (NRC, 1989), and is prefered over grass hays by horses (Cymbaluk, 1990; LaCasha *et al.*, 1999; Rodiek and Jones, 2012).

Forage can be conserved through an ensiling process where anaerobic fermentation of non-structural carbohydrates occurs (NRC, 2007a). As ensiled forages are harvested at an earlier stage of maturity than hay (Peiretti and Bergero, 2004; Connysson *et al.*, 2006; Ragnarsson and Lindberg, 2008), they have a higher nutritive value than corresponding hays (Hale and Moore-Colyer, 2001; Bergero and Peiretti, 2011).

Cereal grains are commonly added to feed rations to increase the dietary energy as most young horses require more energy and protein than forage can provide alone (Moore-Colyer and Longland, 2000; Connysson *et al.*, 2006; Brown-Douglas, 2012). There is a growing interest in high-energy, fibre-based feeds as an alternative to providing dietary energy through grain (Murray *et al.*, 2005). Energy dense fibrous feeds support the normal function of the hind gut and may reduce digestive problems (Miraglia *et al.*, 2006; Willing *et al.*, 2009), while the risk of developmental orthopaedic disorder may be decreased by feeding young horses low starch diets (Miraglia *et al.*, 2006).

THESIS OUTLINE

This thesis is presented as four chapters. Chapter 1 reviews the relevant literature outlining the industry practices of New Zealand Thoroughbred breeders, the importance of the growth of Thoroughbred foals in the racing industry, the concept of feeding foals high energy forage diets and the nutrition related disorders that are associated with feeding high concentrate feeds to foals. Chapter 2 examines the growth of grazing Thoroughbred weanling horses supplemented with either a fibre-based or concentrate-based feed at moderate and then high feeding levels under commercial conditions typical of the Thoroughbred breeding industry in New Zealand. This chapter also looks at the effect of these two supplementary feeds on the occurrence and severity of gastric ulceration. Chapter 3 examines the voluntary feed intake and apparent digestibility of the ensiled lucerne and cracked maize feed by Thoroughbred weanling horses. The minimum duration of total faecal collection that is required for accurate apparent digestibility measures is also determined in this chapter. Chapter 4 discusses the implications of the findings of this thesis to the New Zealand Thoroughbred breeding industry.

1.2 LITERATURE REVIEW

1.2.1 New Zealand Thoroughbred Industry

The New Zealand Thoroughbred industry is currently ranked eleventh on an international scale based on the number of horses starting races per season (5,610), and tenth on the number of foals (4,183) produced out of 45 countries (IRPAC, 2013). The New Zealand Thoroughbred racing industry consists of 62 racing clubs, 50 race tracks which hold 325 racing meets with 2880 Totalised Agency Board (TAB) races annually and supports 12,048 full time employment positions (IER, 2010). During the 2008-2009 year, the New Zealand Racing Industry, comprised of Thoroughbred, Harness, and Greyhound racing contributed more than $1,635 million (0.90% GDP) to the New Zealand economy, of which Thoroughbred racing was responsible for 70.7% (IER, 2010).

New Zealand has a strong reputation for breeding high quality, internationally competitive race horses (Fennessy, 2010), with the exportation of horses overseas being the main focus of the Thoroughbred industry (Morel *et al.*, 2007; Waldron *et al.*, 2011). The main export markets for New Zealand Thoroughbred horses are Australia, Malaysia, Hong Kong and Macau (IER, 2010). During the 2010-2011 year 1,600 Thoroughbreds, with a combined estimated value of $150 million, were exported (NZTR, 2012).

The sale of Thoroughbred yearlings is essential for the New Zealand Thoroughbred industry to remain successful in the international market (Stowers *et al.*, 2010). Approximately 1,500 yearlings (24% of the foal crop) are offered for sale at the New Zealand Bloodstock National Yearling Sales series each year (Waldron *et al.*, 2011). In 2013 an aggregate of $72.4 million was generated by the sale of 1,023 yearlings at auction (New Zealand Bloodstock, 2013). The majority (65%) of revenue from the yearling sales is generated from overseas buyers (IER, 2010).

The success of New Zealand-bred Thoroughbred racehorses overseas is thought to stem from the influence that climate and pasture play during the rearing process (Goold, 1991). The mild climate of New Zealand permits pasture growth throughout the year, and allows the New Zealand equine industry to be mainly pasture-based

(Pearce *et al.*, 1998). Because of this, horse breeders are able to achieve acceptable growth rates in foals raised outdoors on pasture throughout the year (Goold, 1991; Hoskin and Gee, 2004; Rogers *et al.*, 2007), at a low per unit cost if pasture is efficiently utilised (Stowers *et al.*, 2009). Pasture-raised horses have an unrestricted opportunity to exercise (Morel *et al.*, 2007), and early exercise in young horses may be of benefit to the musculoskeletal system (Firth, 2006).

Most New Zealand horse pastures are comprised of approximately 80-95% perennial ryegrass (*Lolium perenne*), and 5-20% white clover (*Trifolium repens*) (Goold, 1991; Hoskin and Gee, 2004; Rogers *et al.*, 2007). Pasture in the Manawatu region of New Zealand has been reported to have an average digestible energy content of 11.4 MJ/kg dry matter (DM) (approximately 9.3 MJ/kg/DM of metabolisable energy (ME)), and a DM digestibility of 62% in weanling horses during winter (Grace *et al.*, 2003). The ME (MJ/kg DM) and crude protein (CP %DM) content of commercial horse pastures throughout New Zealand (Auckland, Waikato, Manawatu, Wairarapa, Canterbury and Otago/Southland) are shown in table 1.1 (Hirst, 2011). Pasture may not always provide adequate levels of energy and protein required for optimal growth, especially in mature summer pastures and when pasture availability is low during winter (Hoskin and Gee, 2004). Many New Zealand pastures are also known to be deficient in selenium (Grace *et al.*, 2002). Selenium deficiency in foals can result in white muscle disease (nutritional muscular dystrophy), a degenerative disease involving skeletal and cardiac muscle (Löfstedt, 1997).

Table 1.1 Metabolisable Energy (ME) and Crude Protein (CP) content of commercial horse pastures throughout New Zealand during summer, winter, and early spring (Hirst, 2011).

	Summer pasture	**Winter pasture**	**Early spring pasture**
ME (MJ/kg DM)	9.25	11.24	12.63
CP (% DM)	18.61	23.14	26.57

While foals may sample forages and their dams' concentrate feed during their first two months of life, the majority of the nutrients they consume are still provided through the mare's milk (Crowell-Davis *et al.*, 1985; Becvarova and Buechner-Maxwell, 2012). As the nutritional quality and volume of the mare's milk begins to decrease, foals become more reliant on forage and concentrate feeds to fulfil their nutrient requirements (Staniar, 2013). Weaning is a very psychologically, physically and nutritionally stressful event for foals (Warren *et al.*, 1998), and is often associated with temporary loss in appetite and subsequently decreased growth rates (Knight and Tyznik, 1985; Lewis, 1995; Griffin *et al.*, 1996; Apter and Householder, 1996; Cuddeford, 1996; Rogers *et al.*, 2007). The provision of good quality creep feed and forage prior to weaning can significantly reduce weaning stress (Lewis, 1995; Apter and Householder, 1996), and may decrease neophobic responses to supplementary feed introduced after weaning (Waran *et al.*, 2008).

In the Thoroughbred racing industry most are weaned at between four and six months of age (Rogers *et al.*, 2004). In practice the decision of when to wean is often influenced by the foal's age, size and the season (McCall *et al.*, 1987; Rogers *et al.*, 2004). The two most common methods of weaning in the Thoroughbred breeding industry are abrupt and progressive weaning (Rogers *et al.*, 2004). Abrupt weaning involves complete auditory, visual and olfactory isolation of mare and foal by placing them in different paddocks, stalls, stables, or removing one of them from the property (Apter and Householder, 1996; Waran *et al.*, 2008). Progressive or gradual weanling involves removing one mare from a herd of mares and foals every few days (Holland *et al.*, 1996; Rogers *et al.*, 2004). The first mare removed is normally the dam of the oldest or most independent foal (Apter and Householder, 1996; Waran *et al.*, 2008). An older or non-lactating 'nanny' horse is often placed within the cohort of young weaned foals to provide a stable behavioural influence (Rogers *et al.*, 2004).

In a cross-sectional survey of Thoroughbred stud farms in the North Island of New Zealand abrupt box weaning was the most common method of weaning and was practiced on 83% of the farms, while progressive weaning was practiced on the remainder by 17% of stud farms (Stowers *et al.*, 2009). Concentrate feed was provided to 85% of foals prior to weaning, and to 100% of foals at weaning on the stud farms

(Stowers *et al.*, 2009). This study estimated that weanling Thoroughbred horses received approximately 47 MJ of digestible energy (DE) (79% of NRC (2007a) requirements) from concentrate feeds alone at five months of age (Stowers *et al.*, 2009). Another study reported that weanling Thoroughbred foals were fed an average of 2.9 kg (range 1-6 kg) of concentrate feed per foal per day following weaning while at pasture (Rogers *et al.*, 2007).

As Thoroughbred breeders receive the majority of their revenue through the sale of yearling horses at auction, the main focus for the breeding sector is to produce foals that will not only be sold at yearling sales (Chezum and Wimmer, 1997; Stowers *et al.*, 2009), but will maximise sales returns (Waldron *et al.*, 2011).

Early handling and education of foals may begin at weaning (Bolwell *et al.*, 2010), with some farms frequently bringing weanlings into stables for further education, including leading, and wearing covers prior to the start of yearling preparation (Stowers *et al.*, 2009). Yearling preparation is the period when New Zealand Thoroughbred stud farms begin to prepare yearling horses for the annual New Zealand Bloodstock National Yearling Sales series at Karaka in January and February each year. Yearling preparation normally begins in November (Stowers *et al.*, 2009); approximately 13 weeks prior to the yearling sales, but this can range from 6-20 weeks depending upon individual farm management practices (Rogers *et al.*, 2007). At twelve months of age, yearlings receive approximately 64 MJ, of DE from concentrate alone (81% of NRC (2007a) requirements) (Stowers *et al.*, 2009).

A combination of stabling and pasture turnout was recorded in 92% of stud farms surveyed in the North Island of New Zealand during sales preparation, with 63% of farms allowing yearlings to spend more than 12 hours at pasture per day throughout the preparation period (Bolwell *et al.*, 2010). Controlled exercise of yearlings either in the form of hand walking, use of a mechanical walker or lunging was performed on 80% of farms, and began approximately 10 weeks prior to the yearling sales. The majority of stud farms did not measure wither height or body weight of yearlings. Body condition of yearlings was assessed ‘by eye’ on 20% and subjectively scored or graded on 11% of farms (Bolwell *et al.*, 2010).

1.2.2 Growth of the horse

Thoroughbred breeders obtain a significant portion of revenue through the sale of yearling horses at auction (Morel *et al.*, 2007), hence, yearlings need to be well grown and in good condition to ensure they reach an acceptable size for the yearling sales (McMeniman, 1996; Grace *et al.*, 2002). In the southern hemisphere the official birth date of Thoroughbred horses is the first of August, regardless of the horses' actual age (Brown Douglas *et al.*, 2005). Breeders aim for foals to be born as soon as possible after this date (Brown Douglas *et al.*, 2005), in order to produce foals that will appeal to potential buyers at yearling sales (MacCarthy and Mitchell, 1974; Waldron *et al.*, 2011). Physical size is important to buyers wanting to race a horse as a two-year-old, with physically older yearlings thought to have a competitive advantage in two-year old races (MacCarthy and Mitchell, 1974). Larger horses tend to have more racing starts in their career (Smith *et al.*, 2006), and pressure within the Thoroughbred industry to produce horses capable of racing as two-year-olds has resulted in a significant demand for physically advanced yearlings (Waldron *et al.*, 2011). As a result of this, the auction price of Thoroughbred yearlings is influenced by physical appearance as well as pedigree (MacCarthy and Mitchell, 1974). Yearlings that received auction bids above the session median are generally heavier, taller, and also slightly older than those that received below the session median prices (Pagan *et al.*, 2005). Yearlings that do not reach the physical development that is desired by buyers may sell for less than satisfactory prices (MacCarthy and Mitchell, 1974), or not at all.

Growth of the horse is normally measured by kilograms (kg) of body weight, and the rate of growth is commonly expressed as average daily gain (ADG: kilograms of body weight gained per day) (Pagan *et al.*, 1996; Jelan *et al.*, 1996; Frape, 2010). Other measurements of growth include wither and hip height, heart-girth circumference, body length (point of shoulder to point of buttock) and cannon bone circumference (Hintz *et al.*, 1979; Thompson, 1995; Kavazis and Ott, 2003). Colts are generally heavier than fillies at the same age (Hintz *et al.*, 1979; Thompson, 1995; Pagan *et al.*, 1996).

The size of the foal at birth can be influenced by several factors including the month, and year of birth, dam age, and foal sex (Hintz *et al.*, 1979; Kocher and Staniar, 2013). At birth horses weigh approximately 10% of their mature body weight (Frape, 2010). It is important for the stud managers to optimise foal birth weight as birth weight is correlated (R^2=0.61) with mature body weight (Hintz *et al.*, 1979), and heavier foals at birth are heavier throughout life (Brown Douglas *et al.*, 2011). While birth-weight was not found to be associated with racing success (Whittaker *et al.*, 2012), many horses with low birth weights are not put into training, and those lighter foals that do end up racing, often do not outperform horses with heavier birth weights (Platt, 1978).

The most rapid growth of the foal occurs *in utero* during late pregnancy (Staniar *et al.*, 2005), where the last 80% of fetal growth (in terms of birth weight) occurs in the last four months of pregnancy (7-11 months) as shown in figure 1.1 (Pagan, 2005b). In the first few months of post-natal life Thoroughbred foals experience a period of rapid growth, with an ADG of approximately ≥1.6 kg/day from birth to one month of age, and 0.91 kg/day from one to four months of age (Jelan *et al.*, 1996). During this early rapid growth the foal receives the required nutrients for intense growth from a combination of mare's milk, pasture, and supplementary feed (Brown Douglas *et al.*, 2011).

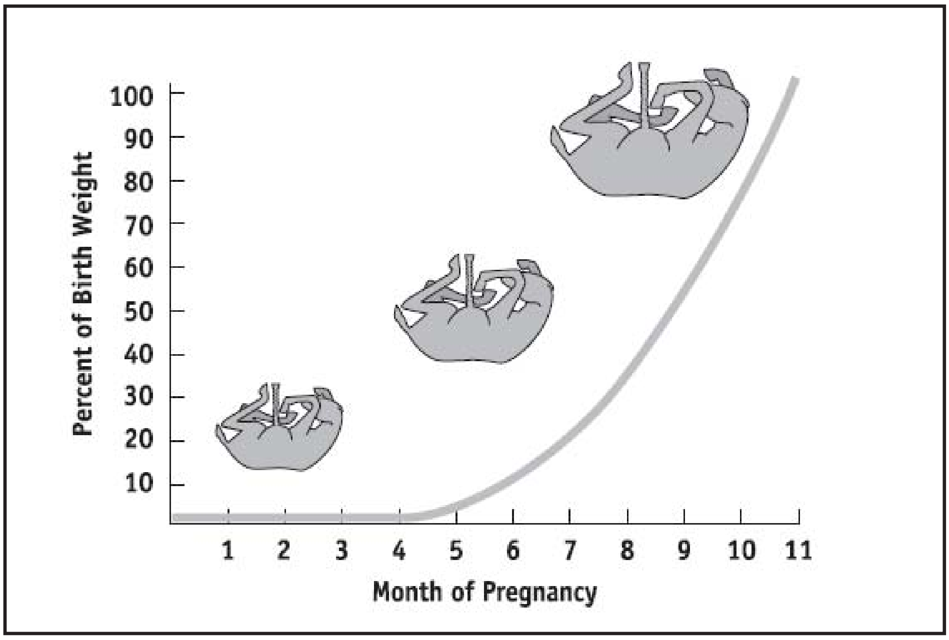

Figure 1.1 Normal growth curve of the horse fetus during pregnancy as a percentage of birth weight (Pagan, 2005b).

The horse goes through four distinct growth phases after birth: with the most rapid growth phase occurring shortly after birth (Staniar *et al.*, 2004b). Foals experience a check in growth rate from approximately 0.8 to 0.6 kg/day at weaning (Brown Douglas *et al.*, 2005), following weaning the growth rate increases again (approximately 0.8 kg/day) (Brown Douglas, 2003), before finally decreasing as the animal approaches maturity (Staniar *et al.*, 2004b), to approximately 0.6 kg/day from 10-17 months of age (Grace *et al.*, 2002). The growth pattern of the foal should produce a smooth curve that is steep in the first few months of life, then levels out around two years of age (NRC, 1989). The growth curves of 2,184 Thoroughbred foals (34,044 body weight measurements) from birth to two years of age from 1977 to 2007 in the United Kingdom, Ireland and United States are shown in figure 1.2 (Kocher and Staniar, 2013). A flexible sigmoid curve is the best descriptor of growth in the horse; however, short-term deviations in growth as a result of environmental elements have an impact on the long-term growth pattern (Staniar *et al.*, 2004b).

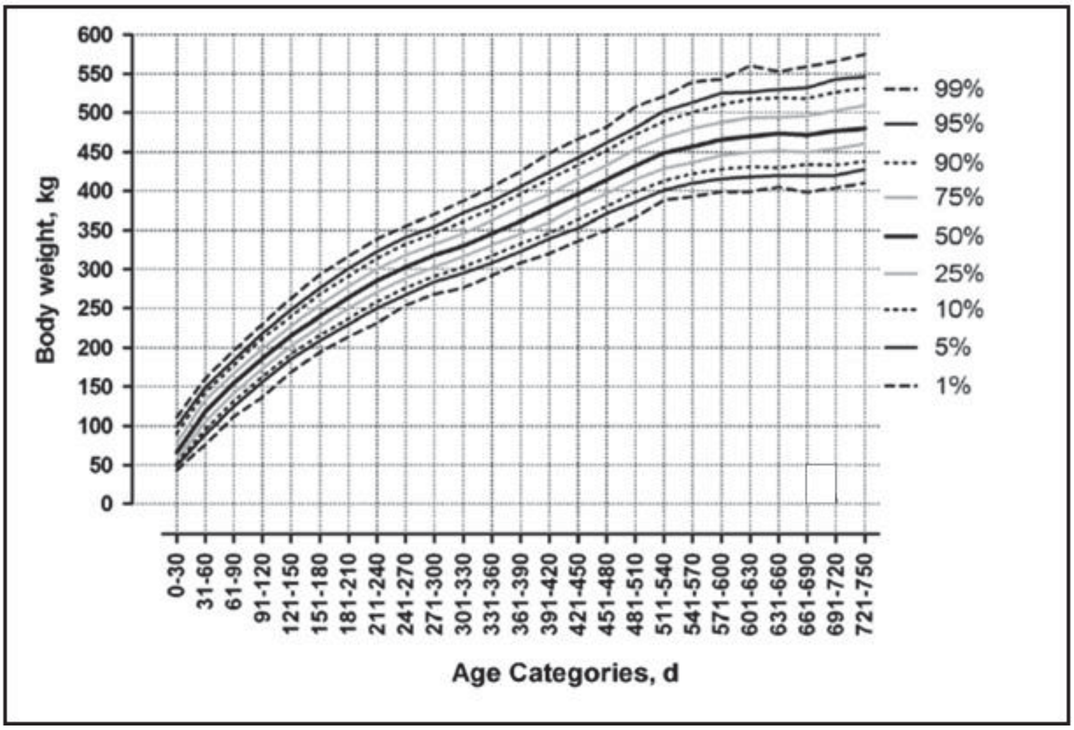

Figure 1.2 Percentiles for body weight of Thoroughbred horses from birth to two years of age (Kocher and Staniar, 2013).

Regardless of weaning age, the ADG of foals is likely to decrease during the week following weaning (Warren *et al.*, 1998, Brown Douglas *et al.*, 2005). The extent to which an individual is affected by the stress of weaning will influence the length of time that is required for the foal to recover and return to its maximum growth rate (Lewis, 1995). A decrease in ADG of 0.2 kg/day following weaning was reported in pasture-fed Thoroughbred foals in New Zealand (Brown Douglas *et al.*, 2005).

From six to ten months of age, growth rates are influenced by seasonal and environmental factors such as temperature and pasture growth. Weanling growth rates decrease during winter, when pasture may not provide adequate nutrition for optimum growth, and increase in spring, as temperatures and pasture growth increase (Hintz *et al.*, 1979; Kronfeld *et al.*, 1996; Pagan *et al.*, 1996; Brown Douglas *et al.*, 2005; Frape, 2010). By 12 months of age, foals attain approximately 60% of their mature body weight, 90% of their mature height and 95% of their final bone growth (Frape, 2010).

The risk of conformational defects and non-septic musculoskeletal conditions is higher in foals that are heavier at birth (Whittaker *et al.*, 2012), and the risk of individual young horses developing skeletal disorders is increased by excess body weight and rapid growth (Cymbaluk *et al.*, 1990; Ruff *et al.*, 1993; Pagan *et al.*, 1996). However, there is no clear definition of what constitutes growth rates that are too rapid or body weights that are too excessive in young horses (Gee *et al.*, 2005; Staniar, 2013).

Monitoring the growth of young horses through regular measuring and weighing of foals allows breeders to identify and rectify the growth of individual foals with growth patterns that are either too slow or too rapid (Pagan, 2005a; Morel *et al.*, 2007; NRC, 2007a). By doing this, health risks that are related to under or over feeding can be quickly identified and reduced by adjusting nutritional and feeding management accordingly to maintain steady growth rates (Staniar, 2004; Pagan, 2005a). Accurate body weight measurements of young horses also allows stud managers to formulate nutrient requirements and to accurately calculate dosage rates of anthelmintics, antibiotics or sedatives (Jones *et al.*, 1989; Staniar *et al.*, 2004a; Rodriguez *et al.*, 2007).

When weighing scales suitable for horses are not available to measure body weight, there are numerous equations that can be used to estimate body weight (Carroll and Huntington, 1988; Staniar, 2004). Body weight can be predicted from linear measurements of heart-girth circumference and body length (Carroll and Huntington, 1988). However, as data from mature horses is used to create body weight estimation equations, they are often not suitable for use on growing horses with rapidly changing body shapes (Kavazis and Ott, 2003). Weight tapes are often inaccurate at estimating the body weight of young horses; but they can be used to gauge comparative changes in weight (Staniar, 2004).

New Zealand Thoroughbred horses raised on pasture alone with no feed supplementation can achieve similar body weights at 6 and 12 months of age to those raised in America, Canada and Ireland, who are fed grain rations into addition to pasture (Thompson, 1995; Jelan *et al.,* 1996; Pagan *et al,.* 1996; Kavazis and Ott, 2003). Weather conditions can have a large influence on whether young horses in the northern hemisphere are kept indoors or at pasture (Jelan *et al.,* 1996; Harris, 1999). The body weights (kg) of New Zealand and northern hemisphere Thoroughbred horses are compared in table 1.2.

Table 1.2 Comparison of horse body weight (kg) data from northern hemisphere and New Zealand Thoroughbred growth studies at different ages (month).

Study	**Number of horses**	**Body weight at 6 months of age (kg)**	**Body weight at 12 months of age (kg)**	**Location**
Brown Douglas *et al.* (2005)	56	253	362	New Zealand
Grace *et al.* (2003)	17	261 (SE±4.8)	377 (SE±18.3)	New Zealand
Pagan *et al.* (1996)	350	253	342	Kentucky
Thompson (1995)	106	259 (SE±1.64)	364 (SE±2.16)	Kentucky
Ringler and Lawrence (2008)	215 204	254 -	- 367	Kentucky/ Virginia
Hintz *et al.* (1979)	1992	240.5	363.9	Canada
Kavazis and Ott (2003)	128	237 (SE±1.64)	338 (SE±2.35)	Florida
Jelan *et al.* (1996)	798	240 (SE±0.62)	340 (SE±0.89)	Ireland

1.2.3 Feeding Thoroughbred weanlings

The use of concentrate rations (cereal grains) to increase dietary energy is widespread in equine diets (Drogoul *et al.*, 2001). To ensure that Thoroughbred foals are grown correctly and achieve growth rates that will maximise returns at yearling auction sales (Morel *et al.*, 2007), their main source of digestible energy is normally provided through concentrate rations, which are high in hydrolysable carbohydrates (Drogoul *et al.*, 2001; Andrew *et al.*, 2006; Vervuert *et al.*, 2009; Willing *et al.*, 2009; Warren *et al.*, 2011).

In a survey of New Zealand Thoroughbred stud farms, 85% of Thoroughbred weanling horses were introduced to concentrate feed prior to weaning, and all weanlings received concentrate rations at weaning (Stowers *et al.*, 2009). On average these weanlings received 79% and 81% of their daily DE requirements (60 and 79 MJ/weanling/day, respectively) (NRC, 2007a) from concentrate feed at five and twelve months of age, respectively, while being kept at pasture (Stowers *et al.*, 2009). In a survey of Thoroughbred and Quarter Horse racing horse stud farms in Texas, concentrate feed (in most cases the mare's feed) was available to foals from their first day of life on over 70% of stud farms. By two months of age foals were eating concentrates on 90% of stud farms, and after weaning most stud farms provided the weanlings with 50% of dietary roughage (Gibbs and Cohen, 2001).

Providing foals with creep feed can assist in developing the microbial population within the foal's gastrointestinal tract (Staniar, 2013), which is influenced to a large extent by available dietary substrates (Durham, 2009). Thus creep feeing with concentrate rations may assist in establishing the microbial population that will be required to utilise the high-starch rations that foal will be fed later in life when they enter race training (Rogers *et al.*, 2007; Williamson *et al.*, 2007). However, feeding low forage and high starch diets can result in gastrointestinal disorders and disturbance of the gastrointestinal microbial population (Luthersson *et al.*, 2009; Willing *et al.*, 2009). Feeding a solely forage diet may encourage a more stable gastrointestinal microbial population in the horse, compared to feeding a feeding a mixed forage/concentrate diet (Willing *et al.*, 2009).

Feeding grain-based meals can increase post-prandial plasma glucose and insulin concentrations and may increase the risk of weanlings developing insulin resistance (Ralston, 1996; Treiber *et al.*, 2005; Pagan *et al.*, 2001; Ralston *et al.*, 2009). Feeding horses high grain diets can also increase the risk of gastric ulceration (Flores *et al.*, 2011), and feeding foals high levels of DE may increase the risk of developing osteochondrosis (Savage *et al.*, 1993).

Thoroughbred foals can reach acceptable growth rates on good quality pasture alone (Grace *et al.*, 2003; Brown Douglas *et al.*, 2005), yet many stud farms feed concentrate rations to foals at pasture. This is mainly due to the difficulty in measuring pasture consumption of the foal (Kronfeld *et al.*, 1996), and uncertainty in knowing if the foal's nutritional requirements are being met by the composition and quality of the pasture (Stowers *et al.*, 2009; Hirst, 2011). This is especially true when the growth rates of foals decrease during winter following a decline in pasture growth and supplementation is required (Pagan *et al.*, 1996; Flores *et al.*, 2011) to alleviate this depression of growth.

It is important for young horses to consume good quality forage to maintain gastrointestinal health (Flores *et al.*, 2011), and forage should be fed as the main component of dietary dry matter (DM), comprising at least 1% of the horse's body weight per day, although most horses will consume up to 1.5-2% of their body weight (Brown-Douglas, 2012).

Lucerne (*Medicago sativa*) hay is a popular forage for feeding horses (NRC, 1989; Small, 1996, Crozier *et al.*, 1997), and weanling horses have been shown to achieve good growth rates fed solely lucerne hay diets (Cymbaluk, 1989). While lucerne hay can meet the requirements for horses at maintenance, grass hays do not fully meet crude protein and most mineral requirements for horses at maintenance when fed as a sole diet (Crozier *et al.*, 1997).

Feeding practices are needed that optimise horse growth, while maintaining overall health (Flores *et al.*, 2011), and support the horses' natural digestive and metabolic functions and natural behaviour (Jansson and Lindberg, 2012, Ringmark *et al.*, 2013). The digestive physiology and anatomy of the horse is designed to utilise large quantities of high-fibre, fresh forage (Harris and Arkell, 1999; Kiley-Worthington, 1990), and in their natural habitat they will spend between 16 and 18 hours grazing daily (McGreevy, 2004; Hill, 2007).

Several studies have compared the growth of foals supplemented with isoenergetic diets: either high starch and sugar (SS) or high in fat and fibre (FF), and found no difference between diet type and growth rate (Ropp *et al.*, 2003; Nicol *et al.*, 2005; Hoffman *et al.*, 1996; Wilson *et al.*, 2007). However, foals that received high FF rations had lower stress levels at weaning than foals that were fed high SS rations (Holland *et al.*, 1996; Nicol *et al.*, 2005; Staniar *et al.*, 2007; Wilson *et al.*, 2007), and the behaviour of foals fed the high FF rations was more consistent and calmer than foals fed the high SS rations (Nicol *et al.*, 2005; Wilson *et al.*, 2007).

Feeding a high fibre to concentrate ratio can dilute the energy content of the concentrate and regulate intake (Cymbaluk, 1989). However, horses that are fed hay and grain rations have a tendency to consume the grain portion of their diet quickly before slowly eating the hay portion (Flores *et al.*, 2011). Similarly, isocaloric dies are consumed at a quicker rate when fed as a pelleted ration in comparison to a chaff ration (Argo *et al.*, 2002).

An alternative to feeding horses concentrate feeds to meet energy requirements may be to provide horses with high energy forage, such as ensiled forages (Connysson *et al.*, 2006). The practice of feeding ensiled forages to horses is becoming more popular (Hale and Moore-Colyer, 2001; Peiretti and Bergero, 2004; Müller, 2005; Bergero and Peiretti, 2011). Ensiled forages are harvested at an earlier stage of maturity than hay (Peiretti and Bergero, 2004; Connysson *et al.*, 2006; Ragnarsson and Lindberg, 2008), and as a result, they are of higher nutritive value than corresponding hays (Hale and Moore-Colyer, 2001; Bergero and Peiretti, 2011).

The energy requirements of adult Standardbred horses in race training can be met through feeding high energy ensiled forages (Connysson *et al.*, 2006; Muhonen *et al.*, 2008; Jansson and Lindberg, 2012). Yearling Standardbred horses in race training are able to reach conventional training goals while maintaining normal growth rates on a diet of *ad libitium* ensiled grass (supplemented with small quantities of a lucerne product (conservation method unknown) and beet pulp) (Ringmark *et al.*, 2013).

While high energy forages are capable of meeting the energy requirements for Standardbred horses in race training, they have not been evaluated in relation to the growth of weanling horses.

1.2.4 Gastric ulceration in the horse

Gastric ulceration is a common condition in the horse (Hammond *et al.*, 1986; Anonymous, 1999; Nadeau *et al.*, 2003), that can lead to a reduction in horse performance and subsequent economic loss for horse owners (Husted *et al.*, 2008; Nadeau and Andrews, 2009; Flores *et al.*, 2011). The development of gastric ulceration is a complicated process that involves many variables (Nadeau and Andrews, 2009), and occurs as a disruption to the gastric mucosa of the non-glandular and glandular regions of the stomach (Anonymous, 1999; Reese and Andrews, 2009).

The equine stomach is divided into two distinct regions: the non-glandular (or squamous), and the glandular regions (Anonymous, 1999; Andrews and Nadeau, 1999). The non-glandular region consists of the proximal third of the stomach, while the glandular region covers the distal two thirds of the stomach (Andrews and Nadeau, 1999). These two regions are separated by the *margo plicatus* (MacAllister *et al.*, 1997; Anonymous, 1999; Andrews *et al.*, 2002). The non-glandular and glandular regions of the stomach and the *margo plicatus* are illustrated in figure 1.3.

The non-glandular region of the stomach is lined with stratified squamous epithelium that is covered by squamous mucosa (MacAllister *et al.*, 1997; Andrews and Nadeau, 1999). This region is the most susceptible to acid injury as it does not possess any barrier defences to gastric acid (Nadeau *et al.*, 2003), and it is dependent upon limited contact with acidic secretions to protect it from acid injury (Murray, 1999). Approximately 80-85% of gastric ulceration occurs in this region (Anonymous, 1999; Nadeau *et al.*, 2003), primarily on the lesser curvature at the *margo plicatus* (Murray, 1991; MacAllister *et al.*, 1997).

The glandular region of the stomach is coated with glandular mucosa that secretes hydrochloric acid (HCl) and pepsinogen as well as mucous and bicarbonate to protect this region from acid injury. The glandular region has a wide capillary network and rapid restoration of the epithelium occurs in response to injury (Andrews and Nadeau, 1999; Reese and Andrews, 2009). Approximately 15-20% of ulcers occur in this region (Reese and Andrews, 2009).

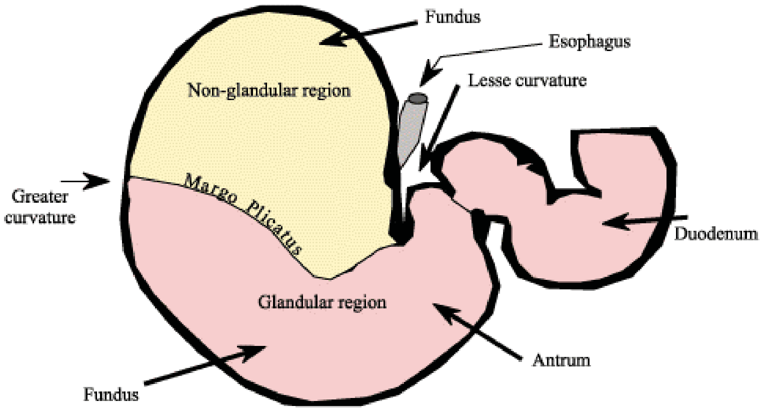

Figure 1.3 A cross section of equine stomach showing *margo plicatus*, glandular and non-glandular regions (Dearo *et al.*, 1999).

The horse continuously secretes gastric HCl, even in the absence of feed (Andrews and Nadeau, 1999; Flores et al., 2011). However, the volume of acid production in the glandular region of the stomach, and exposure of the squamous epithelium in the non-glandular region to gastric acidity, may be influenced by feeding and management practices. These include the horses' feeding behaviour (whether they graze or are 'meal fed'); the size and frequency of meals; the composition of feed offered; the physiological response of the individual horse to feed (Murray, 1999; Reese and Andrews, 2009), and stress experienced by individual horses (Apter and Householder, 1996). The risk of gastric ulceration is increased in horses fed high grain diets, regardless of the grain–processing method used to manufacture the diet (Flores *et al.*, 2011). Horses that are offered grain at a rate above 0.5 kg/100 kg of body weight more than twice a day are at risk of developing gastric ulcers (Andrews *et al.*, 2006).

Gastric ulceration in the equine stomach is associated with the overproduction of gastric acids and hence a low pH (Flores *et al.*, 2011), which initiates primary damage to the non-glandular mucosa of the stomach (Anonymous, 1999; Andrews *et al.*, 2008). The secretion of HCl in the stomach is stimulated by the hormone gastrin (Smyth *et al.*, 1989; Reese and Andrews, 2009). A significant increase in serum gastrin concentrations occurs after feeding a diet high in hydrolysable carbohydrates, while there is little change in serum gastrin concentrations after feeding hay alone (Smyth *et al.*, 1989).

Horses susceptible to gastric ulceration are typically fed high grain diets that contain large portions of hydrolysable carbohydrates (Nadeau and Andrews, 2009). Hydrolysable carbohydrates are fermented by resident stomach bacteria, which produce volatile fatty acids (VFA: acetic, butyric, and propionic acids) (Reese and Andrews, 2009). Hydrochloric acid alone or in combination with other gastric acids (VFAs, lactic acids and bile acids) may act synergistically to create a low acidic environment (pH ≤4) (Nadeau *et al.*, 2003), and cause functional damage to the squamous mucosa (Murray, 1999; Nadeau *et al.*, 2000; Nadeau *et al.*, 2003), rendering the squamous epithelium susceptible to acid irritation and ulceration (Nadeau *et al.*, 2003).

When the stomach of the horse is empty, due to feed being withheld (Reese and Andrews, 2009), gastric acidity can fall to a pH of two or lower (Murray and Schusser, 1993; Anonymous, 1999; Murray, 1999). Prolonged (more than 180 minutes) and repetitive exposure of the squamous epithelium to gastric acids at a pH of four or lower can result in acid injury (Murray and Schusser, 1993; Andrews and Nadeau, 1999; Nadeau *et al.*, 2003), which may develop into gastric lesions and ulceration (Murray, 1994).

Saliva plays an important role in buffering or even increasing gastric pH (Bell et al., 2007a; Reese and Andrews, 2009). The increased volume of saliva that is associated with mastication when the horse eats, can increase the pH of gastric contents by one or two units (Murray and Schusser, 1993). By increasing the pH of the gastric contents above four, the severity of acid-injury to the squamous epithelium is reduced (Nadeau et al., 2003). The ability of saliva to increase the gastric pH is reduced in horses that are fed low forage diets, which predisposes them to gastric ulceration (Bell et al., 2007a).

Lucerne (alfalfa) hay when fed with or without concentrate feeds may have a protective effect on the squamous mucosa in horses as protein and calcium, both of which are present in high levels in lucerne, may buffer the gastric contents (Reese and Andrews, 2009).

Several studies have reported the prevalence of gastric ulceration to be lower in horses grazing pasture (Murray and Schusser, 1993; Murray, 1999; Reese and

Andrews, 2009). During grazing, the gastric pH of the stomach is kept at a pH of four or higher for the majority of the day, as the stomach is buffered by the continuous flow of saliva produced in response to pasture consumption (Bell et al., 2007b; le Jeune et al., 2009; Reese and Andrews, 2009).

However, one study found evidence of gastric ulceration in 67% of pregnant, and 76% non-pregnant grazing broodmares (le Jeune *et al.*, 2009). These mares were maintained on pasture and supplemented with lucerne/grass hay (50:50) (pregnant mares) or lucerne hay (non-pregnant mares) twice a day, with all horses receiving a small portion (900g) of grain daily. The author suggested that the mares may have prioritized the more palatable grain over pasture and lucerne hay, thus reducing the buffering abilities of the grazing and lucerne. Reese and Andrews (2009) speculated that the high prevalence of ulceration reported by le Jeune *et al.* (2009) may be the result of the mares consuming more forage during the day rather than at night, consequently resulting in less saliva production and a lower gastric pH during the night. While pH in the distal portion of the equine stomach remains stable throughout the day, the proximal portion of the stomach has pH levels significantly lower in the early morning hours (1:00–9:00 AM) regardless of housing; suggesting gastric acid secretion may follow a 24 hour circadian pattern (Husted *et al.*, 2008). This finding conflicts with the Equine Gastric Ulcer Council (EGUC), who report that no circadian patterns of gastric acidity have been described in the horse (Anonymous, 1999).

The symptoms of gastric ulceration can be vague (Nadeau and Andrews, 2009), and non-specific (Dionne et al., 2003). They may include poor appetite, colic, poor performance (Vatistas et al., 1999), weight loss (Anonymous, 1999), low body condition scores (Dionne et al., 2003) and rough hair coat (Vatistas et al., 1999).

The most definitive diagnosis of gastric ulceration can be obtained through gastroscopic examination. Several scoring/grading systems have been designed allowing clinicians to evaluate and monitor gastroscopic findings (Anonymous, 1999; Andrews *et al.*, 2002). The Equine Gastric Ulcer Council (EGUC) grading system (shown in table 1.3) has been reported to be more suitable than the number/severity system used by MacAllister *et al.* (1997) and Nadeau *et al.* (2000) as it is easier to use and more repeatable among independent examiners (Bell et al., 2007c).

Table 1.3 Equine Gastric Ulcer Council grading system for grading of equine gastric ulcer syndrome lesions in horses (Anonymous 1999).

Grade	Appearance of gastric mucosa
0	Intact epithelium
1	Intact mucosa, evidence of hyperkeratosis or hyperaemia
2	Small, single, or multifocal lesions
3	Large, single or multifocal lesions or extensive superficial lesions
4	Extensive lesions with areas of apparent deep ulceration

1.2.5 Osteochondrosis

Osteochondrosis (OC) is one of the more frequently occurring developmental orthopaedic diseases (DOD) in the horse (Dik *et al.*, 1999; Vander Heyden *et al.*, 2013), and is of great importance to the equine industry as it contributes to impaired horse welfare (van Weeren, 2006), horse wastage (Rossdale, 1999, Jeffcott, 1991), and economic loss (Stromberg, 1979, Gabel, 1988, Pearce *et al.*, 1998, van Weeren, 2006).

Bone growth occurs rapidly in foals and weanlings (Nunamaker *et al.*, 1990), and OC is dynamic in the early months of life where lesions may appear and regress spontaneously (van Weeren, 2006). The most critical period for preventing DOD is from weaning to 12 months of age (Pagan, 2005b). Osteochondrosis is predominately observed in the stifle and hock of the horse (Dik *et al.*, 1999). As foals grow, they reach a 'point of no return', after which any lesions present are unlikely to regress. The point of no return occurs at five and eight months of age in the hock and stifle, respectively (Dik *et al.*, 1999). Radiograph examination of Thoroughbred yearlings is a common practice at public auction to diagnosis OC before individual sales are finalised (Kavazis and Ott, 2003; Robert *et al.*, 2013). .

The proposed aetiological factors of OC are multifactorial (Jeffcott, 1991; Pagan and Jackson, 1996), and may include genetic predisposition, trauma, nutrition (van Weeren, 2006) and rapid or irregular growth (Stromberg, 1979; Jeffcott, 1991; Firth *et al.*, 1999). Nutritional excesses, deficiencies, and imbalances (Jeffcott, 1991; Jeffcott and Savage, 1996), may enhance the incidence and severity of OC (Pagan, 2005b). An increased incidence of OC lesions were found in foals receiving 129% of NRC (1989) recommended dietary energy requirements (92%) in contrast to control foals fed 100% of NRC (1989) energy requirements (8%) (Savage *et al.*, 1993). These data support the concept of excessive energy consumption influencing rapid growth (Stromberg, 1979), and increased body fat, potentially predisposing young horses to DOD (Pagan and Jackson, 1996). Slow or disturbed growth in early life followed by rapid or compensatory growth can also influence OC (Jeffcott, 1991; Lewis, 1995; Frape, 2010). The presence of OC may also be influenced more in some horses that have a higher insulin and glucose response to a high grain diet than individuals with a normal response (Ralston, 1996; Pagan *et al.*, 2001).

Other factors which may also influence the occurrence of OC development include mares that receive concentrate feeds during gestation may also have an increased risk of their foal developing OC in comparison to mares not fed concentrate feeds (Vander Heyden *et al.*, 2013). Foals that are kept exclusively boxed, or a combination of being boxed and access to pasture during the first 12 months of their life are more likely to develop OC than foals raised solely on pasture from birth to 12 months of age (Vander Heyden *et al.*, 2013).

OBJECTIVES

The hypothesis of this study is that fibre-based ensiled lucerne and cracked maize feed will meet the nutritional requirements of grazing Thoroughbred weanlings. In addition fibre-supplemented weanlings will have lower gastric ulceration grades than concentrate-supplemented weanlings.

The objectives of this thesis are to:

Compare the effect of the two supplemental diets, a commercial weanling concentrate feed and the ensiled lucerne and cracked maize feed on the growth of Thoroughbred weanlings managed at pasture under typical New Zealand commercial conditions. (Chapter 2).

Determine if a fibre-based ensiled and lucerne and cracked maize feed is an equivalent supplementary feed to commercial a concentrate-based weanling feed that is commonly fed to Thoroughbred weanling horses on commercial stud farms. (Chapter 2).

Evaluate the effect of these diets on the occurrence and severity of gastric ulceration in Thoroughbred weanlings. (Chapter 2).

Determine the voluntary feed intake and apparent dry matter, crude protein and gross energy digestibility of the ensiled lucerne and cracked maize feed by Thoroughbred weanling horses. (Chapter 3).

Determine the shortest duration of total faecal collection required during apparent digestibility studies to ensure consistent measurements of apparent dry matter, crude protein and gross energy digestibility in Thoroughbred weanling horses. (Chapter 3).

CHAPTER 2 GROWTH OF THOROUGHBRED WEANLING HORSES FED TWO SUPPLEMENTAL COMMERCIAL WEANLING FEEDS

2.1 ABSTRACT

This study aimed to examine the effect of a fibre-based versus a concentrate-based supplementary diet on the growth and occurrence of gastric ulceration of Thoroughbred weanling fillies managed under commercial conditions in New Zealand at two different feeding levels.

Body weight, wither height, body condition score, effusion and physeal scores were recorded weekly in grazing Thoroughbred weanling horses that were fed a fibre-based (ensiled lucerne and cracked maize mix) (group F, n=6) or a commercial muesli type concentrate-based supplement (group C, n=6) for 120 days. These diets were fed at a moderate supplementary feeding level (40 MJ digestible energy/weanling/day) from day 0-59, and then a high supplementary feeding level (70 MJ digestible energy/weanling/day) from day 59-120. Gastroscopy was performed on all weanlings at days 0, 59, and 120. Left and right stifle and hock radiographs were taken at days 0 and 120.

During the moderate supplementary feeding period, as a result of *Streptococcus equi var. equi* infection, three group F weanlings were separated and managed differently (days 37-59), and in the high supplementary feeding period two group C weanlings were separated and managed differently (days 80-115).

Weekly body weight gain was not affected by dietary treatment (p=0.138) or feeding level (p=0.095). Wither height increase was not affected by dietary treatment (p=0.684) or feeding level (p=0.095). Average daily gain was not affected by dietary treatment (p=0.555) or feeding level (p=0.903) throughout the 120 days of the trial. Body condition score was higher in group C than group F (p=0.004) throughout the study, but not affected by feeding level (p=0.406). Weekly body weight gain (p=0.018), and body condition score (p<0.001) and ADG (p=0.054) were all adversely affected in

weanlings presented with clinical signs of *S. equi var. equi*. There was no association of gastric ulceration with diet at days 0, 59 and 120 (p=0.474).

This study indicated that pasture grazed Thoroughbred weanling horses can achieve good growth rates when supplemented with either a fibre- or concentrate-based supplementary feed at moderate and high feeding levels. The growth rate of weanlings infected with *S. equi var. equi* was temporally decreased, but recovered post-infection.

2.2 INTRODUCTION

The breeding of Thoroughbred horses is an important part of New Zealand's equine industry (Morel *et al.*, 2007; Stowers *et al.*, 2009), and the sale of yearling horses provides a large portion of revenue for breeders (Flores *et al.*, 2011). New Zealand Thoroughbred breeders are commercially driven to producing foals as close as possible to 01 August, the official birth date in the Southern Hemisphere (Rogers *et al.*, 2007), to maximise the growing time, and produce large, well grown foals for sale as yearlings (Brown Douglas *et al.*, 2005; Hirst, 2011), in order to achieve maximum financial return (Morel *et al.*, 2007).

Equine production systems in New Zealand are mainly pasture-based, and there is a reliance on pasture for New Zealand horses to acquire a significant portion of their nutrient requirements (Hoskin and Gee, 2004). This differs from the intensive equine production systems in the Northern Hemisphere where grain-based supplementation is required to meet nutritional requirements (Hoskin and Gee, 2004). Growth studies carried out in New Zealand have demonstrated that young Thoroughbred horses can achieve good growth rates when raised exclusively on pasture alone (Grace *et al.*, 2003; Brown Douglas *et al.*, 2005). However, these studies were not carried out under the commercial constraints that are experienced by most New Zealand stud farms, and it is common practice in New Zealand to feed concentrate (cereal grains) rations as supplementary feed to growing Thoroughbred horses, in particular those undergoing sales preparation and training despite the availability of pasture (Stowers *et al.*, 2009; Hirst, 2011). Thoroughbred foals are typically offered these commercially prepared, grain-based feeds formulated for weanlings leading pre- and post-weaning (Hirst, 2011), which provide approximately 50% of their estimated daily DE requirements (Rogers *et al.*, 2007).

A survey of stud farms in New Zealand revealed the feeding regime of Thoroughbred studs is largely based on what has historically worked; with 96% of respondents considering it essential to feed commercial supplementary rations when producing yearlings' for sale (Hirst, 2011). There appears to be significant commercial pressure to feed cereal grains to attain maximum growth as opposed to optimum growth in young Thoroughbreds (Thompson *et al.*, 1988; Hirst, 2011), and yearlings that are not destined for sale are offered less supplementary feed, or none at all (Hirst, 2011). Some Thoroughbred studs surveyed indicated that they provided supplementary feed as a result of not knowing if nutritional requirements are met by pasture (Stowers *et al.*, 2009; Hirst, 2011), while others provide supplementary feed based on horse body condition, and to gain a response that is perceived to be unattainable by pasture alone (Hirst, 2011).

To achieve rapid growth rates, young horses are often fed large quantities of concentrate feed (Warren *et al.*, 2011), which can have an effect on horse welfare (Ringmark *et al.*, 2013), and may influence the risk osteochondrosis in weanling horses (Ralston, 1996). High concentrate diets are also associated with the occurrence of gastric ulceration in horses (Nadeau and Andrews, 2009). Young race horses entering training would benefit from having a reduced level of gastric ulceration (Flores *et al.*, 2011), as gastric ulceration can reduce performance and the cost of treatment also has a large financial impact on horse owners (Nadeau, 2006). Feeding a high fibre diet increases the buffering effect that saliva has on gastric pH, and can reduce the risk of ulceration (Bell et al., 2007a; Reese and Andrews, 2009). One such feed, lucerne (alfalfa) forage may provide a protective effect on, or at least reduce the severity of, gastric ulceration (Nadeau *et al.*, 2000; Lybbert *et al.*, 2007).

There are currently no published data on the effect of feeding an ensiled lucerne and cracked maize supplement on the growth of Thoroughbred weanlings at pasture, and the subsequent occurrence of gastric ulceration. The objective of this study was to compare the effect of two distinct supplemental diets, an ensiled lucerne and cracked maize feed and a commercial weanling concentrate feed on the growth of Thoroughbred weanlings managed at pasture under typical New Zealand commercial conditions, and to evaluate the effect of these diets on the occurrence and severity of gastric ulceration in Thoroughbred weanlings.

2.3 METHODS AND MATERIALS

2.3.1 Animals

The horses used in the study consisted of two cohorts (n=6) of Thoroughbred weanling fillies born and raised on the same commercial Thoroughbred stud farm (Newmarket Lodge Stud, Manawatu, New Zealand). The weanlings were box weaned at approximately six months of age. Prior to the study the 12 weanlings had been managed and fed under the same conditions in two separate cohorts. Ten of the weanlings were sired by the same stallion. All foals were identified using the unique Thoroughbred brands and to aid in identification from a distance unique trial identification numbers were spray painted on the body of each weanling with stock marker paint.

2.3.2 Diets and Management

All weanlings were kept on predominately ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) pasture, in paddocks ranging in size from 0.43 to 1.22 ha. The weanlings were observed daily for any signs of illness, or disease, by the stud master in the paddock during feeding. Pasture availability (kg/DM/ha) was measured weekly with a folding pasture plate meter (Filip's folding pasture plate meter, Jenquip, Palmerston North, New Zealand). Prior to the start of the trial the weanlings had been supplemented with approximately 2.25 kg crushed barley, 0.5 kg Mare Balancer™ (NRM, Viterra, Auckland, New Zealand), 0.75 kg FiberEzy™ (Fiber Fresh Feeds Ltd., Reporoa, New Zealand), per weanling/day (≈43.7 MJ per weanling), which was the typical ration provided to all weanlings on the farm in addition to pasture. At the start of the trial faecal egg counts were taken from a subsample of the trial weanlings and all weanlings were treated with an anthelmintic (UltraMox, Bomac Laboratories Ltd., Auckland, New Zealand) at 5 g/100 kg bodyweight. The weanlings were subsequently treated with the same anthelmintic on day 71 and 120 of the trial.

On day 0 (the beginning of the trial) the weanlings were offered a supplement that was either a fibre (F) or concentrate (C) based ration at isocaloric levels. No acclimation period to the new rations was provided. The fibre (F) ration was an ensiled lucerne (*Medicago sativa*) and cracked maize (*Zea mays*) feed (consisting of approximately

65% lucerne, 35% maize and 5% vitamin and mineral premix with molasses) (FiberSure™, Fiber Fresh Feeds, Reporoa, New Zealand). The concentrate (C) ration was a commercial muesli type weanling concentrate feed that is commonly used on commercial stud farms as a supplementary feed for weanlings, the main ingredients included steam flaked oats, barley and maize, vegetable protein meal, molasses and lucerne chaff, with apple flavouring a minor ingredient (Assett™, NRM, Viterra, Auckland, New Zealand). Table 2.1 shows the nutritive analysis of the fibre and concentrate rations offered to group F and group C. Pictures of the fibre and concentrate feed are shown in figure 2.1.

Table 2.1 Dry matter content and nutrient composition of the fibre and concentrate supplementary feeds (as provided by the manufacturers) on a DM basis that were provided to group F and group C weanlings during the study.

Analysis	**Fibre (F)**	**Concentrate (C)**
Dry matter, %	59.30	87.50
Crude protein, g/kg DM	117.00	136.00
Crude fibre, g/kg DM	148.00	
Fibre (NDF), g/kg DM		227.00
Crude fat, g/kg DM	30.00	57.00
Calcium, g/kg DM	10.00	9.10
Phosphorus, g/kg DM	5.20	5.70
Selenium, mg/kg DM	0.27	0.07
Digestible energy, MJ/kg	11.98	13.63

Figure 2.1 (a) Forage-based supplementary feed that was offered to group F and (b) concentrate (grain-based) supplementary feed that was offered to group C.

The weanlings were fed once a day at 9:00 am and the feed was distributed amongst three large feed bins (figure 2.2) in both treatment paddocks to be consumed over the following 24 hours. Any feed not consumed by 9:00 am the following day was collected, and the weight was recorded for both groups The supplementary rations were initially offered at a moderate feeding level calculated to provide 40 MJ digestible energy (DE)/weanling/day (56% of NRC (2007a) recommendations (71.6 MJ DE/weanling/day), (group F received 5.5 kg; group C received 3.5 kg as fed per weanling per day). On day 60 of the study, the quantity of supplement offered was increased to a high feeding level, providing 70 MJ DE/weanling/day (92% of NRC (2007a) recommendations (76 MJ DE/weanling/day) (group F received 10 kg, group C received 6 kg as fed per weanling per day), until day 120 when the trial ended. Pasture hay was supplemented when pasture DM fell below approximately 1300 kg/DM/ha, as per standard stud management.

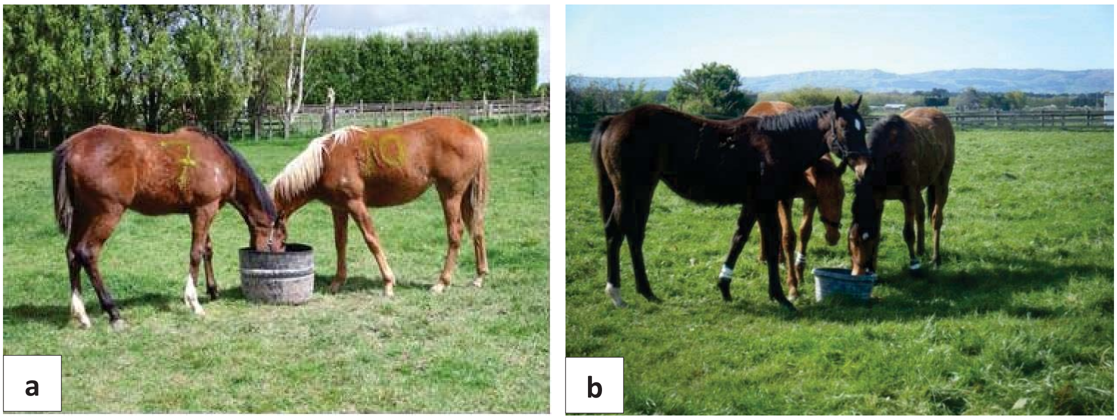

Figure 2.2 (a) Group F weanlings eating the fibre supplementary ration and (b) group C weanlings eating the concentrate supplementary ration from plastic feed bins in their paddocks during the high supplementary feeding period (day 59-120).

2.3.3 *Streptococcus equi var. equi* infection

The weanlings in both group F and group C were exposed to *Streptococcus equi var. equi* following a spontaneous outbreak of strangles on the stud farm. Clinical signs typical of *S. equi var. equi* were observed over days 37-59 in group F (three weanlings), and 80-115 in group C (two weanlings).

2.3.4 Weekly Measurements

At weekly intervals, the weanlings were brought in from the pasture and body weight and wither height were measured; and body condition, joint effusion and physeal scores were assessed. Body weight was recorded to the nearest 0.5 kg using electronic scales (Tru-test 703, True test, Auckland, New Zealand) positioned on a level surface within a loose box. Wither height was recorded at the highest point of the wither using a commercial spirit level measuring stick, while the weanling was positioned standing on level ground within the loose box. Body condition score (BCS) was assessed throughout the study using a modified version of the Henneke *et al.* (1983) 9 point scale, where half scores were given to weanlings that clearly did not fit into whole number categories. Finally, joint effusion and physeal swelling on all four distal limbs of each weanling was semi quantitatively scored using a 0-4 scale (after Ineson *et al.* 2004) by the same person (table 2.2). Joint effusion was assessed in the metacarpophalangeal, metatarsophalangeal, and middle carpal joints, and physeal score was assessed in the medial and lateral distal radius, and medial and lateral distal tibia.

Table 2.2 The physeal scoring method used weekly throughout the study (after Ineson *et al.* 2004).

Grade	Description
0	No swelling
1	Slight swelling
2	Distinct swelling
3	Severe swelling
4	Extreme swelling

2.3.5 Radiographic screening

Radiographs were taken of the left and right tarsus and stifle on days 0 and 120 from 11 of the 12 weanlings. An incomplete set of radiographs (only right stifle) were taken of one group F weanling (#8) on day 0, as this weanling was unable to be sedated to a level that allowed personnel to work safely around her. As there were no radiographs of #8 from day 0 to compare with, none were taken on day 120. Medial/lateral oblique and lateral/medial views were taken of the tarsus, and caudal lateral/craniomedial oblique and lateral/medial views were taken of the stifle with an Elkin Mark 3G Digital Radiography system (Sound-Elkin, California, U.S.A.). Images were screened for the obvious presence of osteochondrosis and graded by the presence or absence of any visible lesion on the joint surface by an experienced equine veterinarian.

2.3.6 Gastric Ulceration

Gastroscopy was performed on the weanlings on days 0, 59, and 120. Ulceration severity was scored in accordance with The Equine Gastric Ulcer Council grading system (Anonymous, 1999) (table 2.3). Weanlings with a grade 2 or higher were deemed to have ulceration (Bell *et al.*, 2007b)**.** The weanlings were fasted for 16 hours prior to gastroscopic examination. Each weanling was sedated immediately prior to gastroscopy with 0.5 ml butorphanol (Ilium Butorgesic, Troy Laboratories, New South wales, Australia) and 2.5 ml of 10% xylazine (Xyla-Ject, Phoenix, Missouri, U.S.A.) administered intravenously. A lubricated endoscope (3 metres in length) (OSF-V60, Olympus, Philadelphia, U.S.A.) was passed through the nasal cavity into the stomach, which was then distended and surfaces were cleaned with air and water to permit visualisation of the mucosal surfaces. The gastroscopic examination included examination of the greater curvature of the *margo plicatus* in the non-glandular portion of the stomach. All gastroscopic examinations and ulcer grading were performed by the same experienced equine veterinarian who examined the radiographs.

Table 2.3 The Equine Gastric Ulcer Council lesion grading system for equine gastric ulcer syndrome lesions in horses (Anonymous, 1999) used to grade gastric ulcer severity in this study.

Grade	Appearance of gastric mucosa
0	Intact epithelium
1	Intact mucosa, evidence of hyperkeratosis or hyperaemia
2	Small, single, or multifocal lesions
3	Large, single or multifocal lesions or extensive superficial lesions
4	Extensive lesions with areas of apparent deep ulceration

2.3.7 Statistical analysis

Data were initially examined using histograms to identify outliers. Analysis of variance (ANOVA) was used to determine the effect of supplementary diet, feeding level, *S. equi var. equi* infection, week and the interaction of feeding level and health on total weight gain in the Thoroughbred weanlings. Linear mixed model analysis was used to determine the effect of supplementary diet and feeding level on body condition score and average daily gain. Wither height was not normally distributed, so the kruskal-

Wallis equality of populations rank test was used to determine the effect of supplementary diet, feeding level, week and health on total height gain over the trial period. The Kolmogorov-smirnov test was used to determine the difference in gastric ulcer scores between dietary treatments.

Data from individual weanlings during the days that they were separated and managed differently from their cohort due to strangles was excluded from the statistical analysis. In group F, data were excluded from weanling #7 on day 37, and weanling #11 and 12 from days 37-59. In group C, data were excluded from weanlings #15 and 16 from days 80-115. Statistical analyses were performed using Stata 8 software (StataCorp LP, College Station, TX, USA). Parametric data is presented as mean ± SE and non-parametric data is presented as median ± IQR. A significance level of $p<0.05$ was set for all tests

2.3.8 Animal ethics

The study was conducted with approval (protocol number 12-51) from the Massey University Animal Ethics Committee (MUAEC), Palmerston North, New Zealand.

2.4 RESULTS

2.4.1 Animal Health

During the moderate supplementary feeding period, on day 37, three weanlings in group F (#7, #11, and #12) were diagnosed with "strangles" (*Streptococcus equi var. equi)* by an equine veterinarian based on their clinical signs of high body temperatures (38.6-39.2°C present in all three weanlings), depression, weight loss, mucopurulent nasal discharge, swollen nasopharyngeal and submandibular lymph nodes (present in #12) (Sweeney, 1996; Timoney, 2011). These weanlings were isolated in stalls from the rest of their group, and fed their normal supplementary diet with *ad libitum* grass hay. Weanling #7 was stalled from days 37-45; and weanlings #11 and #12 were stalled from days 37-59. Weanling #12 exhibited swelling and abscessing of nasopharyngeal and submandibular lymph nodes (that erupted on day 45), weight loss and depression. Weanling #11 remained stalled with a high temperature while also acting as a companion for weanling #12. These three weanlings as well as the remainder of group

F were treated with a ceftiofur antibiotic (EXCEDE®, Zoetis, New Jersey, U.S.A.) intra-muscularly on day 37.

On day 80, during the high supplementary feeding period a second “strangles” outbreak occurred in two group C weanlings (#15 and #16) which both exhibited high temperatures 39.2-39.5°C, swelling and abscessing of nasopharyngeal and submandibular lymph nodes (that erupted on day 87 in #16, and day 94 in #15), weight loss and depression. Both weanlings were moved to an isolation paddock from day 80-115 and their concentrate ration continued to be offered to them. Both weanlings were treated intra-muscularly with EXCEDE® as were the remainder of group C on day 80. No data was collected from weanling #16 on day 80 of the trial.

2.4.2 Diet and pasture availability throughout study

During the moderate supplementary feeding period (day 0-59), both group F and group C consumed their entire daily supplementary rations that were offered to each group. During the high supplementary feeding period (day 60-120), group C consumed their entire daily supplementary rations that was offered to them. However, group F refused an average of 8.5 kg/day (range 1-24 kg as fed) of the supplementary feed on 14 occasions between days 59 and 98.

The weanlings in group F were also supplemented with pasture hay (2 kg/weanling/day) between days 10-31 (moderate supplementary feeding period) when pasture availability fell below 1300 kg/DM/ha. Group C did not receive any pasture hay throughout the trial.

The amount of pasture available on a weekly basis to group F and group C is shown in figure 2.3, with arrows showing when the group F (green) and group C (red) weanlings were moved to different paddocks. During the moderate supplementary feeding period, group F had an mean pasture DM availability of 1505 kg/DM/ha while group C had 2290 kg/DM/ha. During the high supplementary feeding period, group F had an mean pasture DM availability of 1439 kg/DM/ha while group C had 2363 kg/DM/ha. Group C had significantly more pasture available than group F over the whole trial ($p=0.002$).

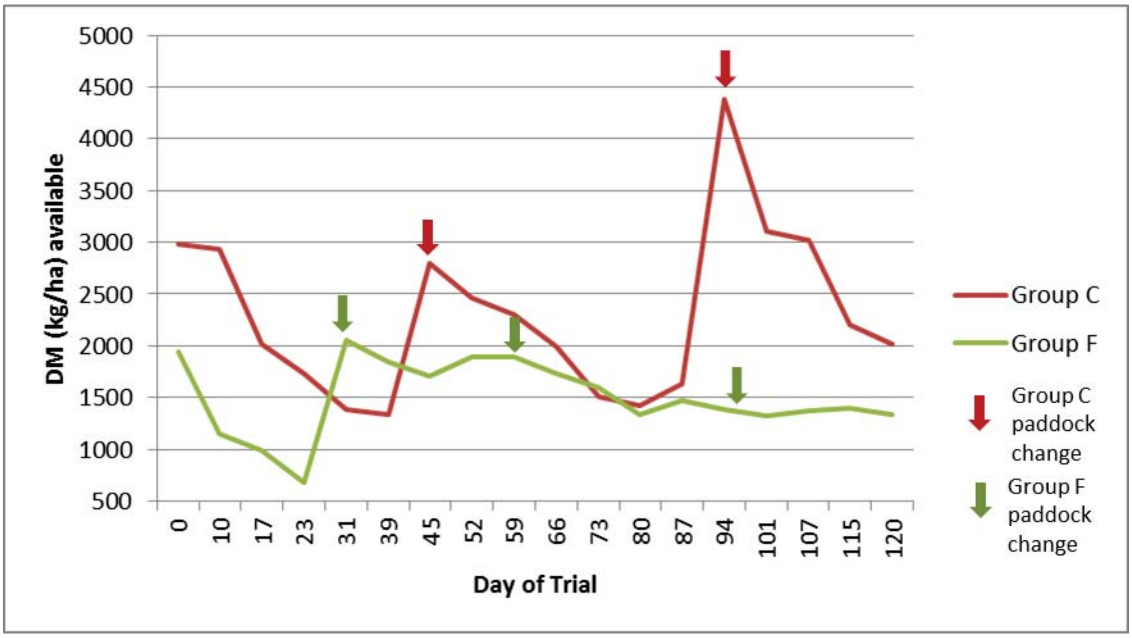

Figure 2.3 Pasture (kg/DM/ha) offered to the group F and group C weanlings throughout the 120 days of the study with arrows showing when group F (green) and group C (red) were moved to different paddocks and the newly available pasture DM.

2.4.3 Growth of weanling horses

At the start of the trial (day 0) group C was heavier (292.7 ± 8.2 kg) than group F (260.0 ± 9.3) (p=0.025). However, there was no difference between groups F and C in age, wither height or BCS (p>0.05). Group C remained heavier (332.2 ± 6.3 kg) than group F (300.8 ± 11.4 kg) at day 59 (p=0.038). Group C also had a higher BCS than group F at day 59 (p=0.049). There was no difference in wither height increase from day 0 to day 59 between groups F and C (p>0.05). At the end of the high supplementary feeding period, and completion of the trial (day 120) group F weighed 339.5 (±11.2) kg, and group C weighed 357.0 (±4.0) kg. There was no difference in body weight, wither height, BCS (p>0.05) between groups F and group C at the end of the trial (day 120) (table 2.4).

Table 2.4 Age (days), body weight (kg), wither height (cm) (mean ± SE) and body condition score (Henneke *et al.*, 1983) of group F and group C weanlings (median ± IQR) at the start of the trial (day 0), at the completion of the moderate feeding (40 MJ/weanling/day) period (day 59), and at the completion of the high feeding (70 MJ/weanling/day) period and growth study (day 120).

Day	Measurement	Fibre (F)	Concentrate (C)	P value
0	Age (days)	242.0 ± 10.0	264.0 ± 4.0	0.079
	Weight (kg)	260.0 ± 9.3	292.7 ± 8.2	0.025
	Wither height (cm)	139.0 ± 1.5	139.4 ± 0.5	0.751
	Body condition score	5.25 ± 6-5	5.5 ± 6.0-5.0	0.721
59	Age (days)	301.0 ± 10.0	323.0 ± 4.0	0.079
	Weight (kg)	300.8 ± 11.4	332.2 ± 6.3	0.038
	Wither height (cm)	141.5 ± 1.5	144.8 ± 0.7	0.073
	Body condition score	5.5 ± 6-4.5	6.25 ± 6.5-5.5	0.049
120	Age (days)	362.0 ± 10.0	384.0 ± 4.0	0.073
	Weight (kg)	339.5 ± 11.2	357.0 ± 4.0	0.173
	Wither height (cm)	145.0 ± 1.3	147.7 ± 0.5	0.084
	Body condition score	5.75 ± 6-5.5	6.0 ± 6.5-6.0	0.156

2.4.3.1 Body weight gain and average daily gain

The mean (±SE) weekly body weights for group F and group C over the 120 days of the trial are shown in figure 2.4. This graph also illustrates the different feeding levels where both groups were fed their supplementary diets at 40 MJ/weanling/day during the moderate supplementary feeding period (day 0-59), and at 70 MJ during the high supplementary feeding period (day 59-120). The time periods when individual weanlings from both groups were managed differently from their treatment group as a result of strangles are shaded on the graph. (Appendices A1 and A2 show the actual weight gain of individual weanlings in group F and group C, respectively over the 120 days of the trial and identify the weanlings affected by strangles). The body weight curve of group F shows a linear pattern, however, in group C there is an obvious deviation from their growth pattern of approximately 56 days between days 59 and 115 during the high supplementary feeding period due to strangles before the weight loss is regained.

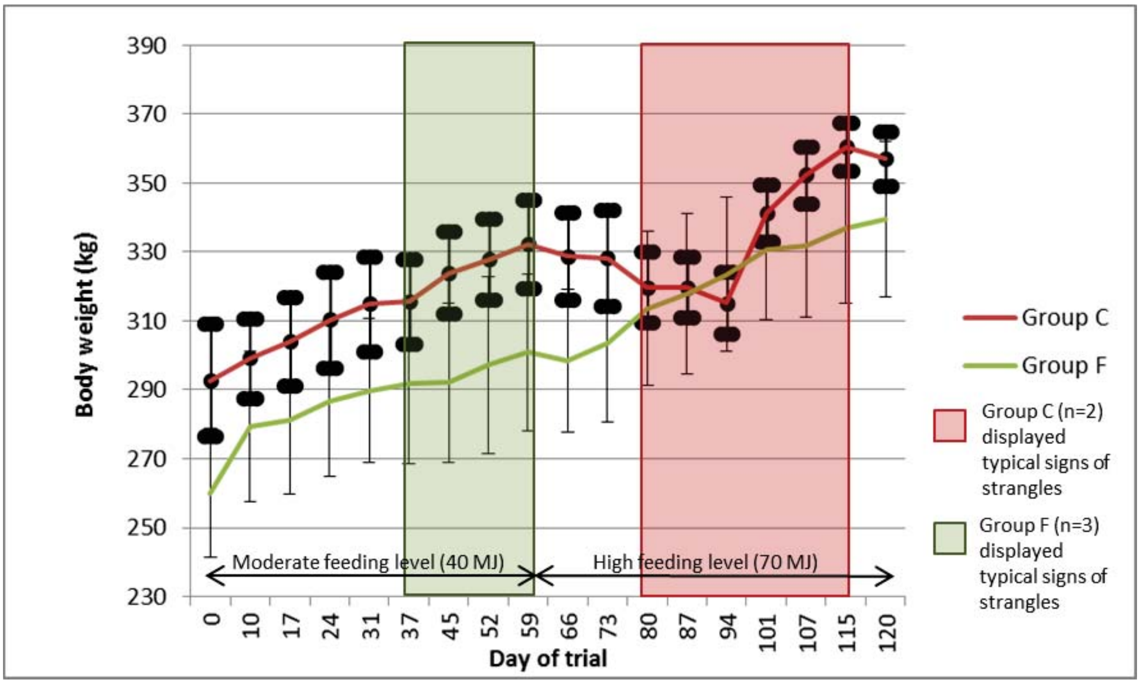

Figure 2.4 Weekly body weights (kg) (mean ± SE) of the group F (n=6) and group C (n=6) weanlings over the 120 days of the study. Shaded areas indicate the time periods where the clinical signs of strangles were observed in three group F (green) weanlings and two group C (red) weanlings. The different supplementary feeding periods are indicated with arrows and the amount of dietary energy (MJ) that was provided per day to each weanling through their supplementary ration.

The mean (±SE) weekly average daily gain (ADG) for group C and group F over the 120 days of the trial are shown in figure 2.5. The actual ADG is calculated by:

Weekly ADG = ((current week's body weight-previous week's body weight)/number of days between measurements)

In figure 2.5, the decrease in the ADG of group C when strangles was apparent is clearly seen between days 73-94 during the high supplementary feeding period. It is not so noticeable between days 37-59 in group F when strangles was diagnosed during the moderate supplementary feeding period. Due to the fluctuation in weekly ADG in figure 2.5, mean ADGs were calculated using the following calculations (these ADGs are presented in table 2.5):

ADG over the entire moderate supplementary feeding period (day 0-59) = ((day 59 BW – day 0 BW)/59 days)

ADG over the entire high supplementary feeding period (day 59-120) = ((day 120 BW – day 59 BW)/61 days)

ADG over the whole trial (DAY 0-120) = ((day 120 BW – day 0 BW)/120 days).

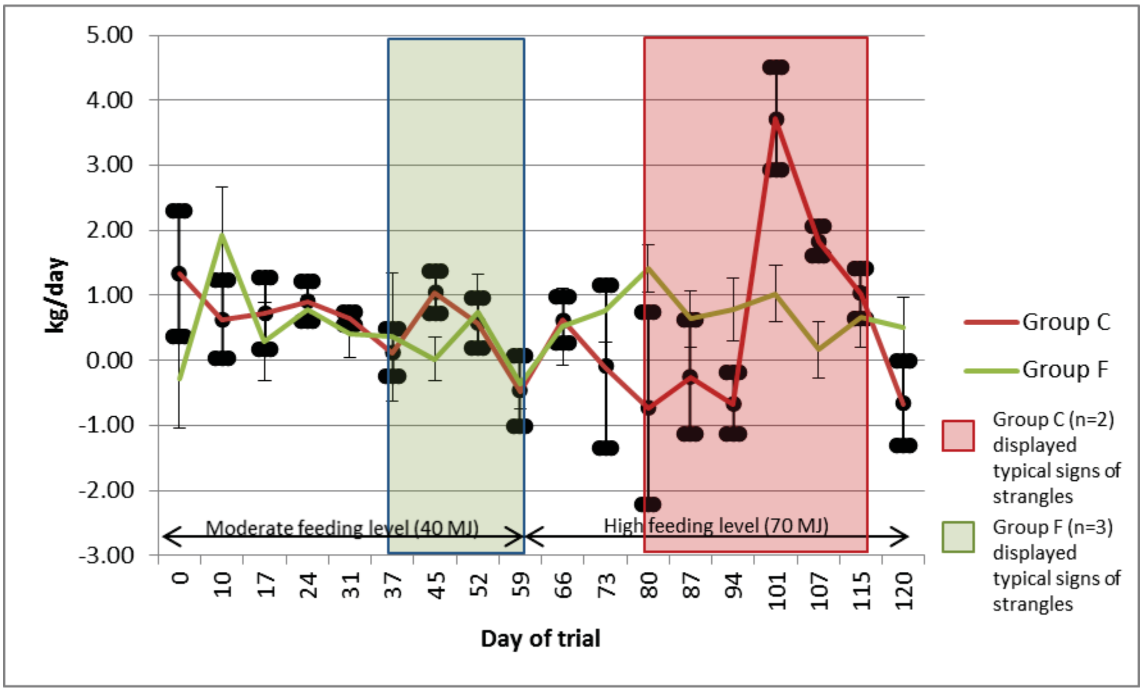

Figure 2.5 Weekly average daily gain (ADG) (kg/day) (mean ± SE) of the group F (n=6) and group C (n=6) weanlings over the 120 days. Shaded areas indicate the time periods where the clinical signs of strangles were observed in three group F (green) weanlings and two group C (red) weanlings. The different supplementary feeding periods are indicated with arrows and the amount of dietary energy (MJ) that was provided per day to each weanling through their supplementary ration.

In table 2.5, the ADG of individual weanlings that were managed differently from their cohort during either moderate (day 0-59) or high (day 59-120) supplementary feeding periods are excluded. In group F, the ADGs of weanlings #11 and 12 were excluded from days 0-59 and 0-120; in group C, the ADG's of weanlings #15 and 16 were excluded from days 59-120 and 0-120. Individual weanlings in group F and group C grew by an average of 0.85 (±0.06) and 0.67 (±0.06) kg/day during the moderate supplementary feeding period (day 0-59), respectively. During the high supplementary feeding period (day 59-120) individuals in group F and C weanlings grew by an average of 0.67 (±0.07), and 0.50 (±0.06) kg/day, respectively. There were no significant differences in ADG between group F and C over the day 0-59, day 59-120, and day 0-120 periods. The ADG of group F and group C weanlings was not affected over the whole trial by dietary treatment (p=0.555) or feeding level (p=0.903).

Table 2.5 The average daily gain (ADG) of group F and group C weanlings (mean ± SE) over days 0-59 during a moderate supplementary feeding period, days 59-120 during a high supplementary feeding period, and days 0-120 over the whole trial.

ADG	**Fibre (F)**	**Concentrate (C)**	**P Value**
ADG from day 0-59 kg/day	0.85 ± 0.06	0.67 ± 0.06	0.078
ADG from day 59-120 kg/day	0.63 ± 0.07	0.50 ± 0.06	0.219
ADG from day 0-120 kg/day	0.71 ± 0.07	0.60 ± 0.04	0.223

Throughout the study, weekly body weight increase was not affected by dietary treatment (p=0.138) or feeding level (p=0.095). There was a significant effect (p<0.001) of week on weekly body weight increase indicating that external factors such as environmental elements affected weight increase.

2.4.3.2 Effect of *Streptococcus equi var. equi* infection on the growth of weanling horses

During the moderate supplementary feeding period (days 0-59), three group F weanlings were managed differently to their cohort for 8-22 days as a result of strangles. The body weights of these weanlings were below their projected growth trajectory for a median of 49 days (range 42-56 days). They lost a median body weight of 14 kg (range 8-19 kg) or 4.7% of their body weight (range 3-6.5%) at their lowest point on a projected growth curve at a median of 21 days (range 14-28 days) following their initial decrease in body weight. The body weight of weanling #11 did not decrease during this period, but was maintained at 263 kg for three consecutive weekly measurements.

During the high supplementary feeding period (days 59-120), two group C weanlings were managed differently from their cohort for 35 days due to strangles. The body weights of these weanlings were below their projected growth trajectory for a median of 52 days (range 48-56 days). They lost a median body weight of 37.5 kg (range 36-39 kg) or 10.6% of their body weight (range 10-15%) at their lowest point on a projected growth curve at a median of 32 days (range 28-35 days) following their initial decrease in body weight.

The remaining four weanlings in group C also showed weight loss, but did not develop any further clinical signs typical of strangles. The body weights of these weanlings were below their projected growth trajectory for a median of 49 days (range 35-56 days). They lost a median body weight of 29.5 kg (range 21-44 kg) or 8.8% of their body weight (range 6-12%) at their lowest point on a projected growth curve at a median of 26 days (range 7-35 days) following their initial decrease in body weight.

Weekly body weight gain was decreased in weanlings #7, 11 and 12 in group F and #15 and 16 in group C over the days that the weanlings displayed clinical signs of strangles (days 37-59 during the moderate supplementary feeding period in group F, and days 80-115 during the high supplementary feeding period in group C ($p=0.018$)). There was no difference in weekly weight gain between group F and group C weanlings during the periods that weanlings displayed signs of strangles ($p=0.277$) (days 36-59 in group F weanlings #7, 11 and 12; and days 80-115 in group C weanlings #15 and 16).

There was a trend for the ADG of weanlings #7, 11 and 12 during days 37-59 (group F) and weanlings #15 and 16 during days 80-115 (group C) to be affected by strangles ($p=0.054$). However, the body condition score of weanlings #7, 11 and 12 during days 37-59 (group F) and weanling #15 and 16 during days 80-115 (group C) was greatly affected by strangles ($p<0.001$). The wither height increase of weanlings #7, 11 and 12 during days 37-59 (group F) and weanlings #15 and 16 during days 80-115 (group C) was not affected by strangles ($p=0.643$).

2.4.3.3 Wither height increase

The mean (±SE) weekly wither heights for group C and group F over the 120 days of the trial are shown in figure 2.6. This figure illustrates the different supplementary feeding periods where both groups were fed their supplementary diets at 40 MJ/weanling/day during the moderate supplementary feeding period and at 70 MJ during the high supplementary feeding period. The time periods when individual weanlings from both groups were managed differently from their treatment group as a result of strangles are shaded on the graph. There was no difference in mean wither height ($p>0.05$) of group F and group C weanlings at day 0, 59, and 120 of the trial.

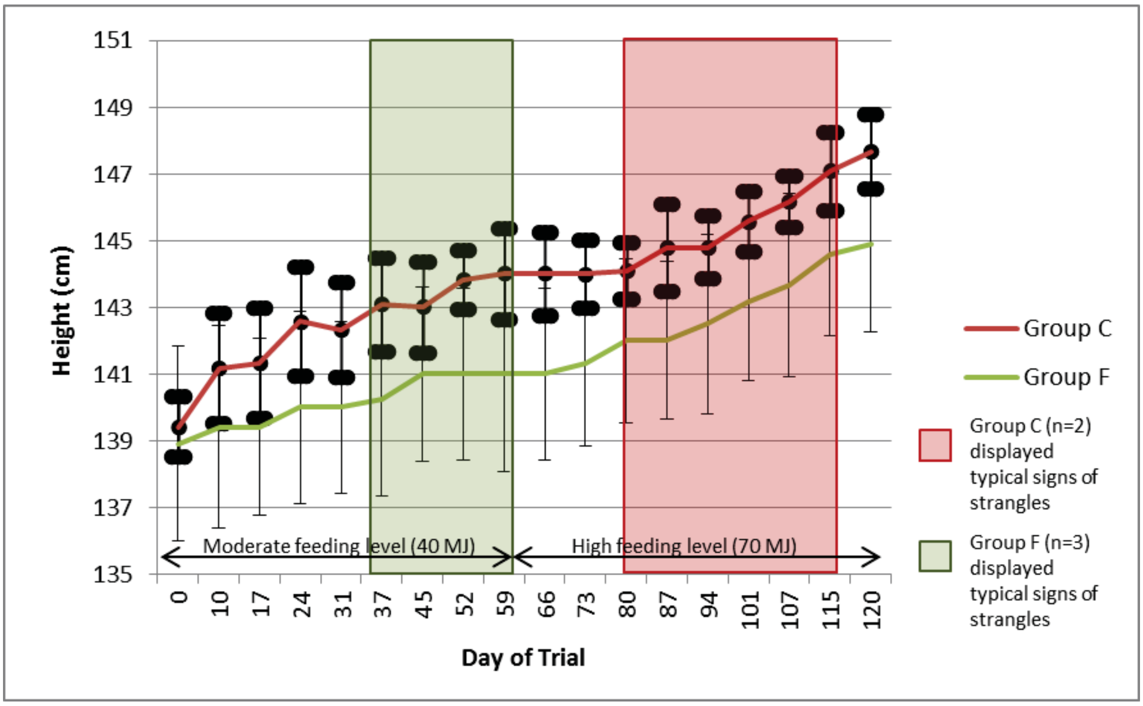

Figure 2.6 Weekly wither heights (cm) (mean ± SE) of the group F (n=6) and group C (n=6) weanlings over the 120 days of the study. Shaded areas indicate the time periods

where the clinical signs of strangles were observed in three group F (green) weanlings and two group C (red) weanlings. The different supplementary feeding periods are indicated with arrows and the amount of dietary energy (MJ) that was provided per day to each weanling through their supplementary ration.

Total wither height increase over the whole trial was not affected by dietary treatment ($p=0.684$) or feeding level ($p=0.095$), however, there was a significant effect of week on height increase ($p<0.001$).

The regression of weekly body weight (kg) and wither height (cm) measurements from all weanlings in group F and group C is presented in figure 2.7. Body weight increase was significantly (Adj/R^2=0.73, $p<0.001$) associated with wither height increase. There was no significant difference ($p>0.05$) in regression slope between group F and group C.

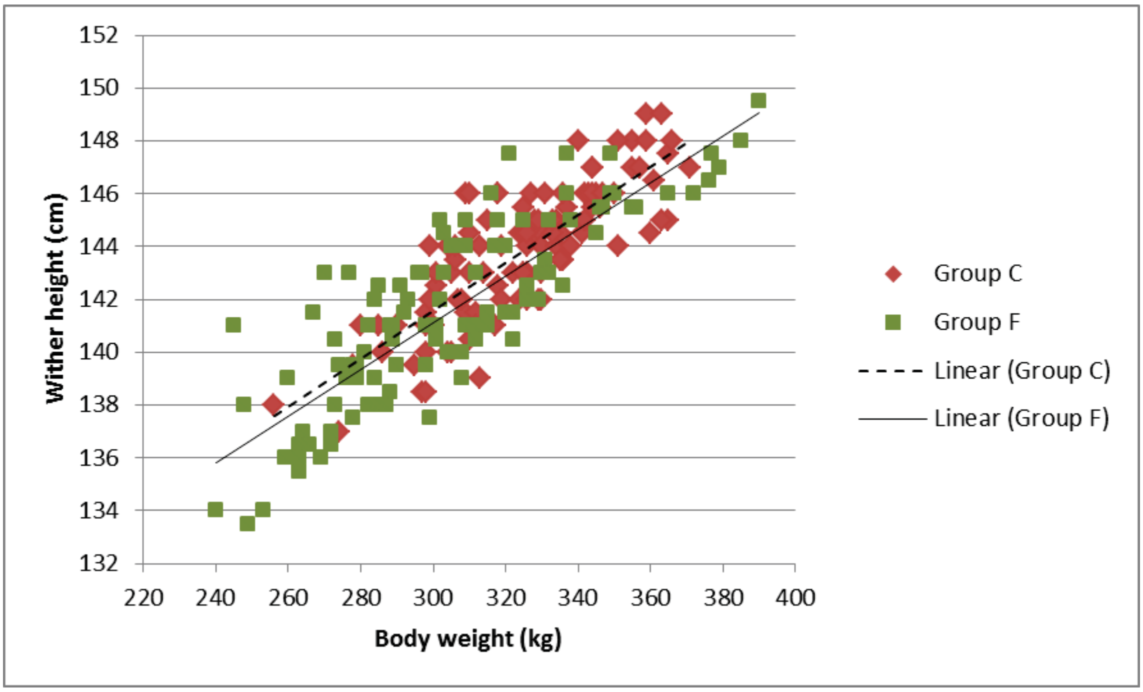

Figure 2.7 Regression of body weight (kg) and wither height (cm) of all weekly body weight and wither height measurements taken from all weanlings in group F (n=6) and group C (n=6) throughout the 120 days of the study.

2.4.3.4 Body condition score

The mean (±SE) weekly BCS assessments for group C and group F over the 120 days of the trial are shown in figure 2.8. This figure illustrates the different supplementary feeding periods where both groups were fed their supplementary diets at 40 MJ/weanling/day during the moderate supplementary feeding period and at 70 MJ during the high supplementary feeding period. The time periods when individual weanlings from both groups were managed differently from their treatment group as a result of strangles are shaded on the graph. While there were wide weekly fluctuations in BCS, there was no difference (p>0.05) in BCS between groups F and C at day 0, and 120, however, at day 59, the end of the moderate supplementary feeding period, group C had a higher BCS than group F (p=0.049). The BCS of group C was higher throughout the study (day 0-120), than the BCS of group F (p= 0.004). Feeding level did not affect BCS throughout the 120 days of the study (p=0.406).

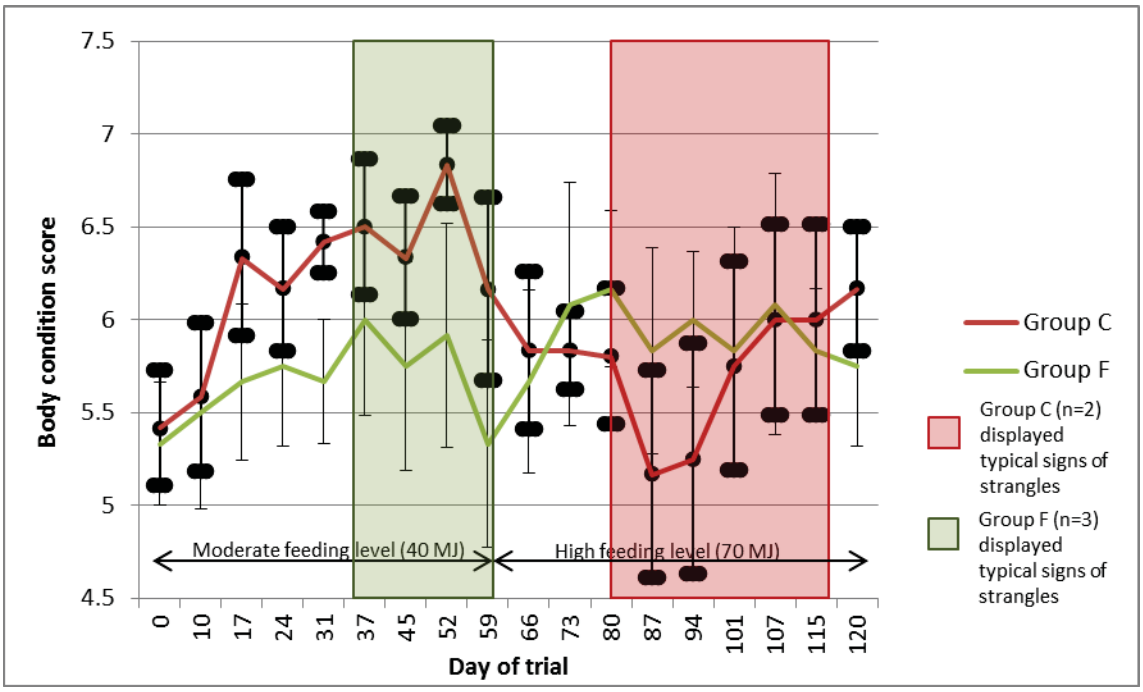

Figure 2.8 Weekly body condition score (mean ± SE) of the group F (n=6) and group C (n=6) weanlings over the 120 days of the study. Shaded areas indicate the time periods where the clinical signs of strangles were observed in three group F (green) weanlings and two group C (red) weanlings. The different supplementary feeding periods are indicated with arrows and the amount of dietary energy (MJ) that was provided per day to each weanling through their supplementary ration.

2.4.4 Percentage of body weight and wither height increase

Body weight and wither height increase were also analysed as a percentage increase from day 0. There was no difference between group F and C in the percentage increase in body weight ($p>0.05$) during the moderate (day 0-59) supplementary feeding period, or over the whole study (day 0-120), however, during the high supplementary feeding period (day 59-120), group F had a greater percentage increase in body weight than group C ($p=0.032$).

The percentage increase in wither height was higher in group C than group F during the moderate (day 0-59) supplementary feeding period ($p=0.001$), and over the whole study (day 0-120) ($p=0.026$), however, there is no difference in the percentage increase in wither height between group F and group C during the high supplementary feeding period (day 59-120) ($p=0.570$) as shown in table 2.6. Appendices A3 and A4 show the percentage increase in body weight and wither height (mean ± SE), respectively for group F and group C over the moderate (day 0-59), and high (day 60-120) supplementary feeding period and over the whole study (day 0-120).

Table 2.6 Percentage increase in body weight and wither height in group F and group C weanlings (mean ± SE) during the moderate (40 MJ/weanling/day; day 0-59) and high (70 MJ/weanling/day; day 59-120) supplementary feeding periods, and over the whole trial (day 0-120).

	Fibre (F)	Concentrate (C)	P value
Body weight % increase from day 0-59	13.88 ± 2.00	13.67 ± 1.51	0.935
Body weight % increase from day 59-120	15.02 ± 1.90	8.67 ± 1.70	0.032
Body weight % increase from day 0-120	26.92 ± 2.44	22.35 ± 2.76	0.242
Wither height % increase from day 0-59	1.86 ± 0.30	3.82 ± 0.31	0.001
Wither height % increase from day 59-120	2.47 ± 0.51	2.09 ± 0.38	0.570
Wither height % increase from day 0-120	4.33 ± 0.49	5.92 ± 0.35	0.026

2.4.5 Radiography results

There was no radiographic evidence of osteochondrosis lesions in the hock and stifle occurring during this study. A small bone cyst was present on the left stifle of one group C weanling (#15) during both day 0 and day 120 radiographs.

2.4.6 Physeal abnormalities and joint effusion

No evidence of physeal abnormalities were observed in either group during weekly assessments throughout the trial. Joint effusion (of a score 1) was observed on five occasions in different weanlings independent of dietary treatment, twice in the metatarsophalangeal joint and three times in the middle carpal joint.

2.4.7 Gastric Ulceration

The gastric ulcer severity grades assigned to the weanlings over gastroscopic examinations at day 0, 59 and 120 ranged from 0.0 to 2.5. There were no significant differences in gastric ulcer grades between group F and group C at days 0 (p=0.474), 59 (p=0.474), and 120 (p=0.474) (individual ulcer scores are presented in appendix A5). At day 0, one weanling (group F) had an ulcer grade of 2 or higher. At day 59 one weanling (group C) had an ulcer grade of 2 or higher. At day 120 three weanlings had ulcer grades of 2 or higher (one in group F and two in group C). Images of the non-glandular portion of the stomach of the same weanling (#8: group F) at day 0 (grade 0) and day 120 (grade 2) are shown in figure 2.9.

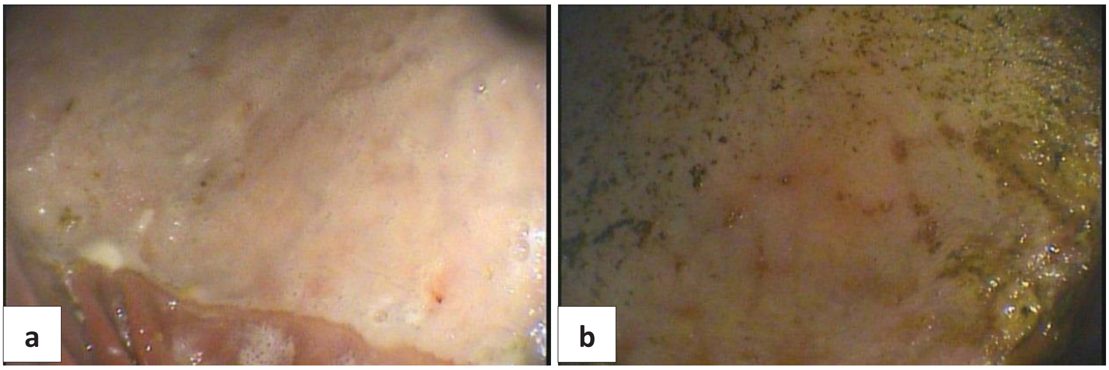

Figure 2.9 Images of (a) the *margo plicatus* in the non-glandular portion of the stomach at day 0 (grade 0) and (b) the non-glandular portion of the stomach at day 120 (grade 2) in the same weanling (#8: group F).

2.5 DISCUSSION

2.5.1 Animal health

Initially six Thoroughbred weanling fillies were purchased at weanling sales and were brought onto the farm to be part of the study along with six residential weanling fillies. Fifty two days after arrival and immediately prior to random allocation to experimental groups on day 0 clinical signs of strangles were observed amongst the weanlings that were purchased from the weanling sales. To facilitate the study within the given timeframe a cohort of six healthy resident weanlings from the farm that were subjected to the same management practices were utilised as an experimental group. Due to this substitution, the two cohorts rather than individual weanlings were randomly allocated to the treatment diets. The decision to keep the weanlings in their original paddock cohorts of six was to prevent any stress that may occur as a result of re-establishing hierarchies, hence the difference between the two groups in body weight and age at day 0 of the current study.

2.5.2 Growth of weanling horses

At the start of the trial, the weanling horses in the current study were of a similar body weight for their age to other Thoroughbred weanlings used in growth studies completed in New Zealand (Brown Douglas, 2003; Grace *et al.*, 2003), North America (Hintz *et al.*, 1979; Thompson, 1995; Pagan *et al.*, 1996; Kavazis and Ott, 2003; Ringler and Lawrence, 2008), and Ireland (Jelan *et al.*, 1996). During the trial the average daily weight gain was similar to that reported for commercial production of Thoroughbred weanlings in New Zealand (Grace *et al.*, 2003; Brown Douglas, 2003) and overseas (Pagan *et al.*, 1996; Jelan *et al.*, 1996; Ringler and Lawrence, 2008). This was expected in the group C weanlings as they were managed and fed as per the commercial conditions that are typical of the New Zealand breeding industry for sale as yearlings. However, for group F weanlings also managed under the same conditions, the effect of the fibre diet on the growth and development of the weanlings was unknown.

Both groups of weanlings displayed similar growth patterns over the 120 days of the study. Group C weanlings were heavier at the start and remained so throughout the study. The higher percentage increase of body weight displayed by group F weanlings during the high supplementary feeding period (day 59-120) reflects the recovery of the group F weanlings that were affected by strangles during the moderate feeding period and the effect that strangles had on the body weight gain of group C during the high supplementary feeding period.

Group C had a higher increase of wither height than group F over the moderate supplementary feeding period (day 0-59) and the whole trial (day 0-120), but not during the high supplementary feeding period (day 59-120). As wither height did not appear to be affected by strangles, this may be due to group C being 22 days older than group F.

2.5.3 Supplementary diets offered to weanling horses

In New Zealand it is commercial practice to rear Thoroughbred weanlings at pasture with the provision of supplementary feed to ensure optimal growth rates are obtained. There is a large range (1-6 kg as fed) in the amount of supplementary feed that is offered to weanlings in New Zealand (Rogers *et al.*, 2007). A New Zealand survey of weanling management estimated that weanlings were offered 78% of their daily energy requirements (47 MJ/DE: NRC, 2007a) in concentrate form following weaning (Stowers *et al.*, 2009). The two levels of feed offered in this trial were used to provide a representation of the "typical" or more moderate supplementary feeding practice and the more ambitious or intense approach to rearing weanlings. As the NRC DE requirements for growing horses may under- or over-estimate energy requirements for individual horses (NRC, 1989; NRC, 2007a), the NRC (2007a) energy requirements for growth were used as a guide to offer supplementary rations at a moderate and high feeding level. In the current study the moderate feeding level (day 0-59) was more conservative than industry practice, offering 40 MJ/DE/weanling/day or 56% of energy requirements for weanlings at eight months of age (NRC, 2007a), while the high feeding level (day 59-120) was more intense, offering 70 MJ/DE/weanling/day or 92% of energy requirements for weanlings at 10 months of age (NRC, 2007a) in concentrate form. The 2007 NRC energy requirements for the weanlings in this trial were calculated using NRC (2007b) for the mean body weight of all 12 weanlings at day 0 (8 months of age) for the moderate supplementary feeding period, and the mean body weight of all 12 weanlings at day 59 (10 months of age) for the high supplementary feeding period.

Concentrate supplementation is often fed to horses as a means of insurance to guarantee that foals met their nutrient requirements to achieve adequate growth as the stud managers are often unsure of how much pasture foals consume in the paddock or the nutritive value of the pasture. While the supplementary rations provided to weanlings in the two groups in the current study were isocalorific, the consumption of pasture was not measured. However, the similar growth pattern between the two groups suggests that the variation in pasture consumption between the two groups was low. During the moderate supplementary feeding period, group F had a mean pasture DM availability of 1505 kg/DM/ha while group C had 2290 kg/DM/ha. During the high supplementary feeding period, group F had an mean pasture DM availability of 1439 kg/DM/ha while group C had 2363 kg/DM/ha.

While the two supplementary diets offered were isocaloric, differences existed in the in the composition of the feeds offered due to one being a fibre-based ration (group F) and the other a concentrate-based ration (group C). These variations in composition meant there was a difference in the DM and wet weight (volume) of feed offered. This may have had an impact on the feeding behaviour of the weanlings. Following the increased feeding level at day 59, group F did not always consume all of the supplementary feed that was offered during the 24 hours that the feed was available. On 14 occasions between days 59 and 98, the group refused an average of 8.5 kg/day of the supplementary feed, equating to 14% (range 1-24 kg as fed) of the fibre ration offered. This may have occurred due to the acceptability of uneaten feed being decreased during wet weather when the DM content would become further reduced by the feed becoming wet.

Horses select food based on what feed is available and what is palatable (Houpt, 1983). Sweet flavoured feeds are highly palatable to horses (Randall *et al.*, 1978; Hawkes *et al.*, 1985; Houpt, 1990), whereas lucerne and cracked maize are much less preferred (Houpt, 1983). Throughout the trial, group C consumed the entire concentrate supplementary ration that was offered to them. Substitution of pasture by concentrate feeds has been observed in dairy cows which reduce grazing time and pasture DM intake when provided with high levels of supplementary concentrates (Stockdale, 2000; Riquelme and Pulido, 2008). The feeding behaviour of the weanlings was also monitored 30 minutes prior to supplementary feed being offered and two hours post-feeding on eight occasions during the moderate feeding period (40 MJ; day 0-59), and seven occasions during the high feeding period for another study (Shotton, 2013). During the moderate (40 MJ) supplementary feeding period (day 0-59) group C consumed their entire supplementary ration within two hours, unlike group F who had 35-65% of their feed remaining on all occasions. Neither group consumed all the supplementary rations that were offered to them within two hours during the high (70 MJ) supplementary feeding period (day 59-120) (Shotton, 2013).

Group F showed an obvious preference for eating pasture over their fibre supplementary feed throughout the trial, especially during the high feeding period (day 59-120) when they did not always consume all of the feed that was offered. A similar grazing behaviour has been shown in other weanling horses which displayed a strong motivation to leave feed bins containing good quality lucerne hay to graze extremely low levels (near dirt) of pasture (Heleski *et al.*, 2002). Group F also displayed more natural 'trickling feeding' behaviour (Hill, 2007), by alternatively grazing pasture and the fibre supplementary ration, while also spending more time moving around the paddock more than group C, who consumed the concentrate ration in long feeding bouts shortly after it was offered during the two-hour period when post-feeding behaviour was monitored (Shotton, 2013).

While feeding high energy concentrate rations can predispose weanlings to nutritional imbalances and digestive issues (Houpt, 1983), feeding highly palatable, energy dense feeds can assist in stimulating appetite and providing nutrients to health compromised horses. The decrease in body weight of all group C weanlings during the high supplementary feeding period (day 59-120) indicated that their appetite was suppressed due to illness and that they were unable to consume enough DE. Group C did continue to ingest their entire concentrate ration but this was eaten in preference to the pasture available in their paddock until day 94 of the trial, when they were moved to a new paddock with a higher amount of pasture available (4378 kg/DM/ha).

2.5.4 *Streptococcus equi var. equi* infection

Foals that are affected by illness or do not receive enough energy may experience a decrease in body weight and ADG (Kocher and Staniar, 2013). Two separate disease outbreaks of strangles were observed between group F and group C during the current study. Other than one group F weanling (#12), which displayed typical symptoms of strangles, only subtle clinical signs were shown among the group F weanlings (high temperatures and weight loss) affected in the outbreak (#7 and 11). The other weanlings in group F (#8, 9 and 10), that did not show clinical signs, did not suffer a loss of body weight during the moderate supplementary feeding period (Day 0-59). In comparison, weanlings in group C were more severely affected, with notable body weight and body condition losses occurring among the four 'healthy' weanlings (#13, 14, 17 and 18), indicating that they may have been sub-clinically affected.

While only two group C weanlings were diagnosed with strangles (#15 and 16), the decrease in body weight and ADG indicated that the remaining 'healthy' weanlings in that cohort may have been sub-clinically affected. Despite ADG data from the infected horses being excluded from day 59 onwards in table 2.5, the lower ADG of the rest of group indicates that the growth rate of the remaining 'healthy' weanlings was also depressed, most likely through these weanlings having a suppressed appetite, as a reduction in voluntary feed intake is often the first sign of many diseases (Forbes, 2007).

In one study, pregnant two and three year old fillies became infected with *Streptococcus equi var. equi* and experienced a mean body weight loss of 9.1% (SE 1.1) (range 0-19.5%) over period of 1-28 days (Wilsher and Allen, 2006). While body weight was affected by illness in the current study, it is impossible to know exactly how much body weight the weanlings in the current study lost due to disease, as they should have been achieving an ADG of approximately 0.6 kg/day, whereas ADGs as low as -2.86 kg/day was recorded in one infected weanling (#15, day 80). Hence, the body weight loss of the affected weanlings can only be estimated based on a projected growth curve.

In other work, poor growth rates were imposed on New Forest foals by maintaining them at a constant body weight from 6-12 months of age through restricted intake. Despite this growth check, skeletal growth continued in the restricted foals, albeit at a much slower rate than that of control foals. At 12 months of age the energy restricted foals were relatively tall, but thinner and shallower than the controls. They were able to almost completely recover their growth trajectory when fed *ad libitum* from 12-18 months of age, demonstrating a considerable ability of the foal to subsequently recover from under nutrition through compensatory growth (Ellis and Lawrence, 1978a,b,c). In the current study, the percentage increase of wither height was higher over the whole study for group C, and illness did not affect wither height growth which agrees with previous work showing skeletal growth is maintained but at a slower rate during dietary restriction (Allden, 1970; Becvarova and Buechner-Maxwell, 2012). Growth plate closure was also found to be delayed in under nourished horses, allowing them to accomplish a near normal sized skeleton when intake is no longer restricted (Ellis and Lawrence, 1978b).

When energy becomes available following a time of energy deprivation, a period of compensatory growth will be experienced by most animals (Dawson *et al.*, 1945; Staniar *et al.*, 2004b). Figures 2.4 and 2.5 indicate that despite suffering a growth check as a result of strangles infection, the group C foals attempted to achieve a normal growth pattern through compensatory growth. While compensatory growth is not ideal in horses, it does enable them to recover from illness or nutritional insult.

2.5.5 Pasture availability and compensatory growth of weanlings

Paddock allocation throughout the trial was dictated by the pasture management practices and stock rotation of the stud manager. The weight loss that occurred in group C between day 59 and 120 does not appear to be a seasonal or pastoral effect as group F was not affected at the same time, and pasture DM availability was not a limiting factor for group C. In fact on days 80 and 87, group C had 1425 and 1638 kg/DM/ha respectively which was 95 and 160 kg/DM/ha more than what was available to group F on the same two days in their paddock.

Group C experienced a sharp increase in ADG on day 101, following their change of paddock to a greater quantity of pasture (4378 kg/DM/ha) on day 94. While this increase may have been influenced by an increase in the weight of gut contents (Forbes, 2007), it is also likely that the weanlings were compensating their earlier weight loss. The paddock that the healthy group C weanlings moved into on day 94 had a tall grass sward height (approximately 25 cm) and was in a vegetative growth phase. These weanlings may have compensated for their body weight loss by maximising their energy intake. Previous work has shown that maximal energy intake can be achieved by taking larger sized bites at a lower bite rate (Fleurance *et al.*, 2009; Edouard *et al.*, 2010).

A series of studies have demonstrated the ability of young horses to recover from impaired growth due to restricted intake by offering *ad libitum* feed (Ellis and Lawrence, 1978a,b,c). In these studies, New Forest foals compensated for body weight loss by increasing their appetite, their efficiency of feed utilisation and their growth rate. Weight loss can be regained at an increased rate when an adequate diet and health conditions are restored (Osborne *et al.*, 1914). These recovery mechanisms have also been reported in other studies of under-nutrition in sheep and cattle (Allden, 1968; 1970). Following the change of paddock on day 94, the start of group C's recovery from illness is shown by a sharp increase in weight gain. However, group C did not completely recover from their body weight loss before the study ended on day 120.

2.5.6 Weekly variability of body weight and wither height measurements

In the current study, large variability existed in body weight and wither height measurements among the weanlings in each group, and also on a week to week basis. While this may also reflect the small population size of this trial, some of the weekly variation in body weight is influenced by stock movement around the stud farm. This is particularly evident in group C at day 101, following their paddock change at day 94. Climatic elements including ambient temperature, solar radiation, wind velocity, precipitation, and relative humidity can affect horses (NRC, 2007a), and pasture growth (Pagan *et al.*, 1996). Climatic variables can also increase voluntary feed intake and digestible energy requirements (NRC, 2007a), however, these variables were not investigated in this study.

There was a large variation in animal size between the group F weanlings. At day 0 the smallest weanling (#11) weighed 240 kg and measured 134 cm in wither height, while the largest weanling (#9) weighted 303 kg and measured 144.5 cm in height. At day 120, #11 was still the smallest (315 kg, 141 cm) and #9 the biggest (390 kg, 149.5 cm). The variation among animals was less among group C weanlings, where weight measurements ranged from 256-313 kg and wither height ranged from 138-141 cm at day 0. At day 120 body weight measurements had increased to 340-366 kg and wither height ranged from 145-149 cm. The large variation between group F animals can also be seen in figure 2.7, which presents the regression of body weight and wither height of all weanlings in group F and group C over the 120 days of the trial.

In the current study, wither height increase was affected by week. Slight variations in individual wither height can occur throughout the day, but not to a significant level (van de Pol and Sloet van Oldruitenborgh-Oosterbaan, 2007). The variation in wither height in the current study is most likely attributed to the difficulty of getting foals to stand still (Rodriguez *et al.*, 2007). Other than being handled during weekly measurements, the only other occasions that the weanlings were handled during the trial included the unpleasant experiences of intramuscular antibiotic injections when they were infected with or exposed to strangles, and when they were sedation for gastroscopy on three occasions. To record an accurate wither height measurement the horse should ideally be positioned with front legs parallel and perpendicular, and toes in line with no more than 1.5 cm difference. The hind legs should both be taking weight, and be as near perpendicular as possible with hind toes no more than 15 cm out of line and the horse should be relaxed with its head in a natural position as raising and lowering of the head in turn raises and lowers the withers which can affect their height by 2-3 cm (Hickman and Colles, 1984). Due to the low levels of handling exposure these weanlings had (which is common on commercial Thoroughbred farms in New Zealand), and their adverse experiences, the weanlings were often tense when they were brought into the loose box to be measured which would have affected their 'true' height, and they frequently had to be held against a wall to make them stand still to be measured. The weanlings were manoeuvred to ensure that their weight was distributed evenly and their front feet were parallel and close to perpendicular before a wither height measurement was recorded, however, this was not always to the extent recommended by Hickman and Colles (1984).

2.5.7 Radiography

With the exception of one weanling having a stifle bone cyst prior to the beginning of the study, which remained throughout the study, the weanling horses in the current study did not show any evidence of osteochondrosis.

2.5.8 Gastric ulceration

When grazing pasture, the horse's stomach is buffered by the continuous flow of saliva (Bell *et al.*, 2007b) and ingesta, which keeps the gastric acid pH at 4 or higher throughout the day (Reese and Andrews, 2009). The weanlings in the current study had access to pasture 24 hours a day (with the exception of feed being withheld 16 hours prior to gastroscopy on three occasions), hence the majority of the time their stomachs would have been buffered by feed. Pasture is often cited as providing protection against gastric ulceration (Murray and Schusser, 1993; Reese and Andrews, 2009), which is reflected in the low gastric ulceration grades seen in the current study. However, gastric ulceration (mild in the majority of horses) was reported to be present in 71% of pregnant and non-pregnant mares grazing pasture supplemented with lucerne and lucerne-grass hay, respectively and 0.9 kg grain. It was suggested that the mares may have selected the grain over the hay and pasture, making them more susceptible to ulceration (le Jeune *et al.*, 2009). At end of the current study 25% of the weanlings had an EGUC grade of 2 or higher. It is of interest to note that weanling #15 in group C who had the higher gastric ulcer grades at days 59 and 120, was observed to spend the most time eating the concentrate feed in her cohort during the two hours post-feeding behaviour monitoring (Shotton, 2013).

2.6 CONCLUSION

In the current study there was no difference in growth between Thoroughbred weanlings supplemented with an ensiled lucerne and maize feed or a commercial weanling concentrate feed at a moderate or high feeding level while managed at pasture under typical New Zealand commercial conditions. The weanlings in the current study achieved growth rates similar to those published in New Zealand and overseas. The different supplementary feeds did not affect the occurrence of gastric ulceration.

The unexpected occurrence of *Streptococcus equi var. equi* infection during the current study gave an insight into the effect of nutritional insult on growth and the ability of foals to rectify weight loss through compensatory growth.

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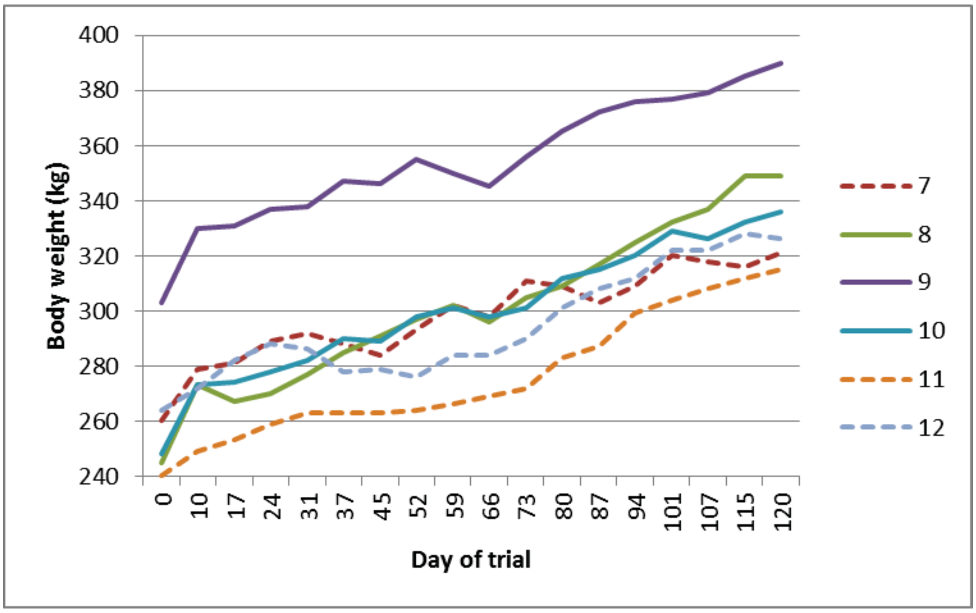
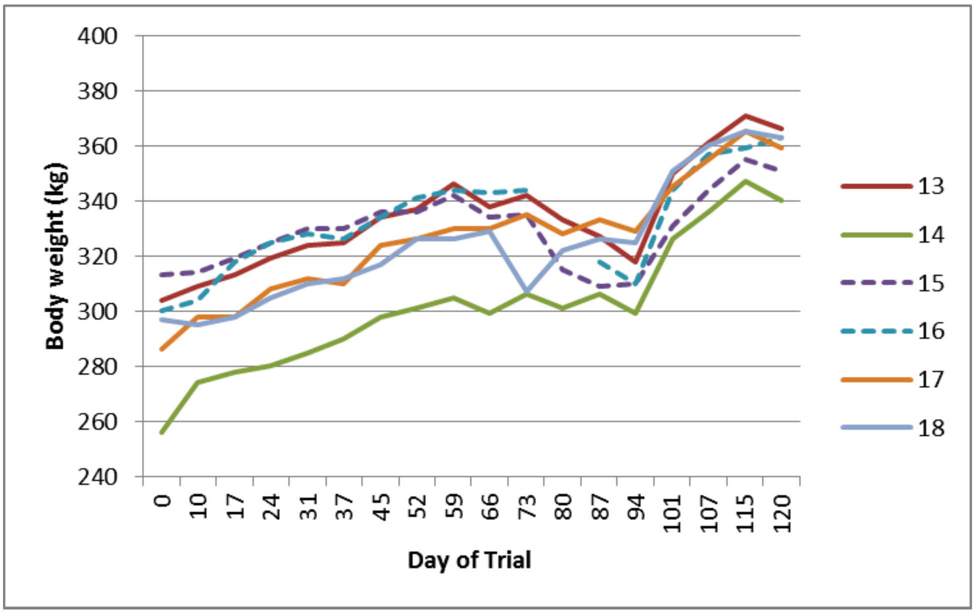
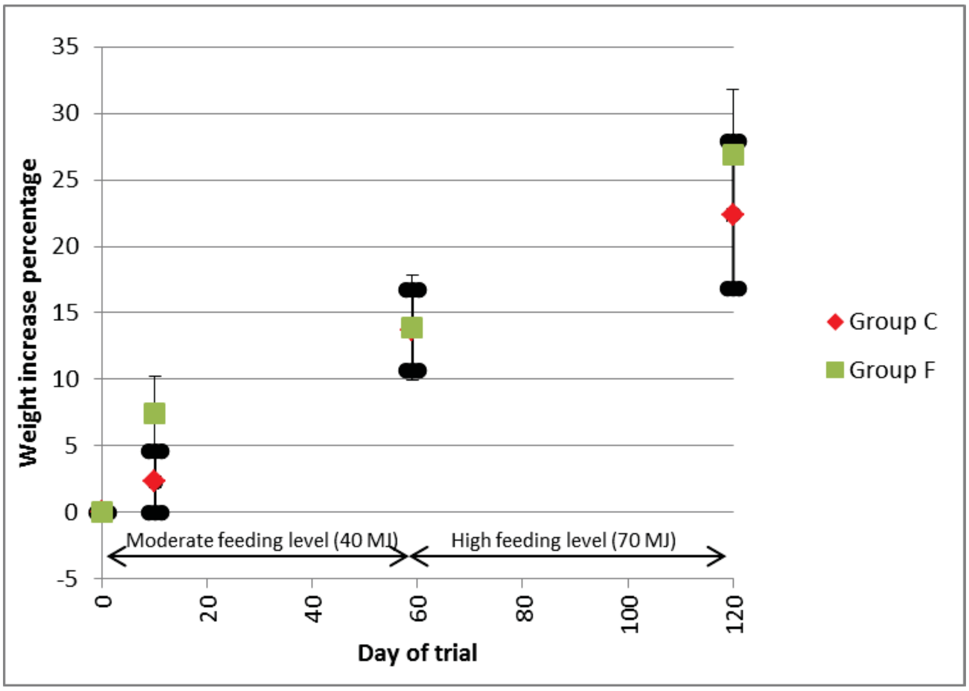
2.8 APPENDICES A



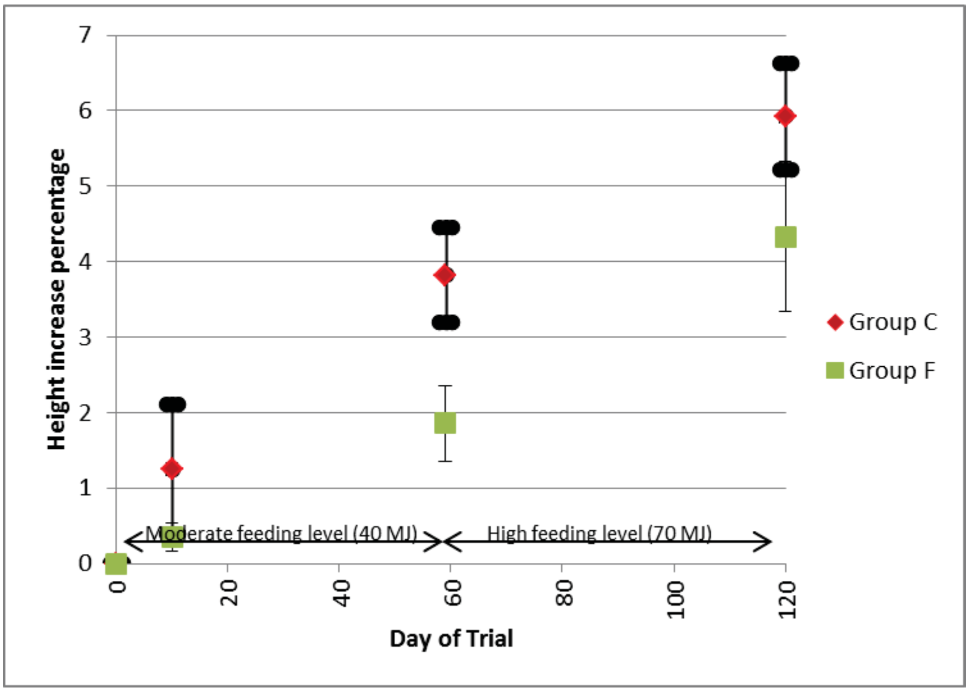
Appendix A1 Body weight (kg) of individual weanlings in group F (n=6) over the whole study (120 days). Dashed lines represent individual weanlings (#7, 11, 12) that were managed differently (days 37-59) due to strangles.



Appendix A2 Body weight (kg) of individual weanlings in group C (n=6) over the whole study (120 days). Dashed lines represent individual weanlings (#15, 16) that were managed differently (days 80-115) due to strangles. No data was recorded from weanling #16 on day 80.



Appendix A3 Percentage body weight increase (mean ± SE) in group F and group C weanlings during the moderate (day 0-59) and high (day 59-120) feeding periods, and over the whole trial (day 0-120).



Appendix A4 Percentage wither height increase (mean ± SE) in group F and group C weanlings during the moderate (day 0-59) and high (day 59-120) feeding periods, and over the whole trial (day 0-120).

Appendix A5 Gastric Ulcer severity grades scored in accordance to The Equine Gastric Ulcer Council (Annonymous, 1999) on days 0, 59 and 120 in group F and group C weanlings. Scores for individual weanlings and the number of counts of the presence of ulceration in each treatment are also shown.

		Day of trial		
Treatment	**Weanling identification**	**0**	**59**	**120**
Fibre	7	1	0	0
Fibre	8	0	1	2
Fibre	9	2	0	0
Fibre	10	0	0	0.5
Fibre	11	1	0	0
Fibre	12	0	0	0.5
COUNT (number with a grade > 0)		3	1	3
Concentrate	13	1	1.5	2
Concentrate	14	0	0	1
Concentrate	15	0	2.5	2
Concentrate	16	0	0	1
Concentrate	17	0	1	0
Concentrate	18	0	0	0
COUNT (number with a grade > 0)		1	3	4

Appendix A6 Changes in the body weight (kg) of grazing weanlings offered fibre- (group F) and concentrate-based (group C) supplementary feeds over 120 days. Measurements recorded of individual weanlings while they were affected by strangles are indicated by *.

Treatment		Group F							Group C						
Weanling		7	8	9	10	11	12	Mean ± SE	13	14	15	16	17	18	Mean ± SE
Day	Feeding level														
0	Moderate	260	245	303	248	240	264	260 ± 9.3	304	256	313	300	286	297	292.7 ± 8.2
10	Moderate	279	273	330	273	249	272	279.3 ± 11.0	309	274	314	304	298	295	299.0 ± 5.8
17	Moderate	281	267	331	274	253	282	281.3 ± 10.8	313	278	319	318	298	298	304.0 ± 6.5
24	Moderate	289	270	337	278	259	288	286.8 ± 11.0	319	280	325	325	308	305	310.3 ± 7.0
31	Moderate	292	277	338	282	263	286	289.7 ± 10.5	324	285	330	328	312	310	314.8 ± 6.9
37	Moderate	288*	285	347	290	263*	278*	291.8 ± 11.7	325	290	330	326	310	312	315.5 ± 6.0
45	Moderate	284	291	346	289	263*	279*	292.0 ± 11.5	334	298	336	334	324	317	323.8 ± 6.0
52	Moderate	293	297	355	298	264*	276*	297.2 ± 12.8	337	301	336	341	326	326	327.8 ± 5.9
59	High	302	302	350	301	266*	284*	300.8 ± 11.4	346	305	342	344	330	326	332.2 ± 6.3
66	High	298	296	345	298	269	284	298.3 ± 10.4	338	299	334	343	330	329	328.8 ± 6.3
73	High	311	305	356	301	272	290	305.8 ± 11.5	342	306	335	344	335	307	328.2 ± 7.0
80	High	309	309	365	312	283	301	313.2 ± 11.2	333	301	315*	*	328	322	319.8 ± 5.6
87	High	303	317	372	315	287	308	317.0 ± 11.8	327	306	309*	318*	333	326	319.8 ± 4.4

94	High	309	325	376	320	299	312	323.5 ± 11.1	318	299	310*	310*	329	325	315.2 ± 4.5
101	High	320	332	377	329	304	322	330.7 ± 10.1	350	326	331*	344*	345	351	341.2 ± 4.2
107	High	318	337	379	326	308	322	331.7 ± 10.2	361	336	344*	357*	355	360	352.2 ± 4.0
115	High	316	349	385	332	312	328	337.0 ± 11.0	371	347	355*	359*	365	365	360.3 ± 3.5
120	High	321	349	390	336	315	326	339.5 ± 11.2	366	340	351	363	359	363	357.0 ± 4.0

Appendix A7 Changes in the wither height (cm) of grazing weanlings offered fibre- (group F) and concentrate-based (group C) supplementary feeds over 120 days. Measurements recorded of individual weanlings while they were affected by strangles are indicated by *.

Treatment		**Group F**							**Group C**						
Weanling		7	8	9	10	11	12	Mean ± SE	13	14	15	16	17	18	Mean ± SE
Day	Feeding level														
0	Moderate	139.0	141.0	144.5	138.0	134.0	137.0	138.9 ± 1.5	140.0	138.0	139.0	141.0	140.0	138.5	139.4 ±0.5
10	Moderate	139.5	141.5	144.0	139.0	133.5	136.5	139.0 ± 1.5	141.5	139.0	143.0	144.0	140.0	139.5	141.2 ± 0.8
17	Moderate	140.0	141.5	143.5	139.5	134.0	138.0	139.4 ± 1.3	144.0	139.5	142.0	143.0	141.5	139.0	141.5 ± 0.8
24	Moderate	141.0	143.0	146.0	139.5	136.0	138.5	140.7 ± 1.4	144.0	141.0	143.0	145.5	142.0	140.0	142.6 ± 0.8
31	Moderate	141.5	143.0	145.0	140.5	136.5	138.0	140.8 ± 1.3	144.5	141.0	142.0	144.5	141.5	140.5	142.3 ± 0.7
37	Moderate	141.0*	142.5	145.5	139.5	135.5*	137.5*	140.2 ± 1.5	144.5	141.0	144.5	144.5	143.0	141.0	143.1 ± 0.7
45	Moderate	142.0	142.5	145.5	140.5	136*	139.5*	141.0 ± 1.3	144.0	141.0	143.5	145.0	142.5	141.0	142.8 ± 0.7
52	Moderate	142.0	143.0	145.5	141.0	136.5*	139.0*	141.2 ± 1.3	145.5	142.5	144.0	144.5	144.0	143.0	143.9 ± 0.4
59	High	142.0	145.0	146.0	140.5	136.5*	139.0*	141.5 ± 1.5	145.5	143.0	146.0	147.0	144.0	143.0	144.8 ± 0.3
66	High	141.0	143.0	145.0	140.5	136.0	138.0	140.6 ± 1.3	144.0	142.0	144.5	146.0	143.0	142.0	143.6 ± 0.6
73	High	141.0	144.0	145.5	141.0	137.0	139.5	141.3 ± 1.2	145.0	143.5	144.5	146.0	143.5	142.0	144.1 ± 0.6
80	High	141.0	145.0	146.0	142.0	138.0	140.5	142.1 ± 1.2	144.5	143.0	145.0*	*	145.0	143.0	144.1 ± 0.5
87	High	143.0	144.0	146.0	141.0	138.0	140.0	142.0 ± 1.2	146.0	144.0	145.5*	146.0*	145.0	142.0	144.8 ± 0.6

94	High	144.0	145.0	146.5	141.5	137.5	140.5	142.5 ± 1.3	146.0	144.0	144.5*	146.0*	145.0	143.0	144.8 ± 0.5
101	High	144.0	145.0	147.5	142.0	140.0	140.5	143.2 ± 1.2	146.0	144.5	146.0*	147.0*	146.0	144.0	145.6 ± 0.5
107	High	145.0	147.5	147.0	142.0	139.0	141.5	143.7 ± 1.4	146.5	146.0	146.0*	147.0*	147.0	144.5	146.2 ± 0.4
115	High	146.0	147.0	148.0	143.0	141.0	142.0	144.5 ± 1.2	147.0	146.0	148.0*	149.0*	147.5	145.0	147.1 ± 0.6
120	High	147.5	146.0	149.5	142.5	141.5	142.5	144.9 ± 1.3	148.0	148.0	148.0	149.0	148.0	145.0	143.9 ± 0.2

Appendix A8 Changes in the average daily gain (ADG: kg BW/day) of grazing weanlings offered fibre- (group F) and concentrate-based (group C) supplementary feeds over 120 days. Measurements recorded of individual weanlings while they were affected by strangles are indicated by *.

Weanling		**Group F**							**Group C**						
	Horse	7	8	9	10	11	12	Mean ± SE	13	14	15	16	17	18	Mean ± SE
Day	Feeding level														
0	Moderate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	Moderate	1.90	2.80	2.70	2.50	0.90	0.80	1.93 ± 0.4	0.50	1.80	0.10	0.40	1.20	-0.20	0.63 ± 0.3
17	Moderate	0.29	-0.86	0.14	0.14	0.57	1.43	0.29 ± 0.3	0.57	0.57	0.71	2.00	0.00	0.43	0.71 ± 0.3
24	Moderate	1.14	0.43	0.86	0.57	0.86	0.86	0.79 ± 0.1	0.86	0.29	0.86	1.00	1.43	1.00	0.91 ± 0.2
31	Moderate	0.43	1.00	0.14	0.57	0.57	-0.29	0.40 ± 0.2	0.71	0.71	0.71	0.43	0.57	0.71	0.64 ± 0.0
37	Moderate	-0.67*	1.33	1.50	1.33	0.00*	-1.33*	0.36 ± 0.5	0.17	0.83	0.00	-0.33	-0.33	0.33	0.11 ± 0.2
45	Moderate	-0.50	0.75	-0.13	-0.13	0.00*	0.13*	0.02 ± 0.2	1.13	1.00	0.75	1.00	1.75	0.63	1.04 ± 0.2
52	Moderate	1.29	0.86	1.29	1.29	0.14*	-0.43*	0.74 ± 0.3	0.43	0.43	0.00	1.00	0.29	1.29	0.57 ± 0.2
59	High	1.29	0.71	-0.71	0.43	0.29*	1.14*	0.53 ± 0.3	1.29	0.57	0.86	0.43	0.57	0.00	0.62 ± 0.2
66	High	-0.57	-0.86	-0.71	-0.43	0.43	0.00	-0.36 ± 0.2	-1.14	-0.86	-1.14	-0.14	0.00	0.43	-0.48 ± 0.3
73	High	1.86	1.29	1.57	0.43	0.43	0.86	1.07 ± 0.2	0.57	1.00	0.14	0.14	0.71	-3.14	-0.09 ± 0.6
80	High	-0.29	0.57	1.29	1.57	1.57	1.57	1.05 ± 0.3	-1.29	-0.71	-2.86*	*	-1.00	2.14	0.74 ± 0.8
87	High	-0.86	1.14	1.00	0.43	0.57	1.00	0.55 ±0.3	-0.86	0.71	-0.86*	-1.86*	0.71	0.57	-0.26 ± 0.4

94	High	0.86	1.14	0.57	0.71	1.71	0.57	0.93 ± 0.2	-1.29	-1.00	0.14*	-1.14*	-0.57	-0.14	-0.67 ± 0.2
101	High	1.57	1.00	0.14	1.29	0.71	1.43	1.02 ± 0.2	4.57	3.86	3.00*	4.86*	2.29	3.71	3.72 ± 0.4
107	High	-0.33	0.83	0.33	-0.50	0.67	0.00	0.17 ±0.2	1.83	1.67	2.17*	2.17*	1.67	1.50	1.84 ± 0.1
115	High	-0.25	1.50	0.75	0.75	0.50	0.75	0.67 ± 0.2	1.25	1.38	1.38*	0.25*	1.25	0.63	1.02 ±0.2
120	High	1.00	0.00	1.00	0.80	0.60	-0.40	0.50 ± 0.2	-1.00	-1.40	-0.80	0.80	-1.20	-0.40	-0.67 ± 0.3

CHAPTER 3 VOLUNTARY FEED INTAKE AND DIGESTIBILITY OF AN ENSILED LUCERNE AND CRACKED MAIZE FEED BY THOROUGHBRED WEANLING HORSES

3.1 ABSTRACT

This study aimed to determine the voluntary feed intake and apparent digestibility of dry matter (DM), crude protein (CP) and gross energy (GE) in an ensiled lucerne (*Medicago sativa*) and cracked maize (*Zea mays*) feed by six Thoroughbred weanling filly horses and to determine the duration of total faecal collection required to ensure consistent measurements of DM, CP and GE apparent digestibility.

An ensiled lucerne and cracked maize feed was offered at 3.2% of body weight as DM to six Thoroughbred weanling filly horses (362 ± 10 days old; 339.5 ± 11.2 kg BW). The weanlings were stalled individually in loose boxes (4 x 4 m) on rubber matting. Voluntary feed intake was measured over 16 days from days 6-21 of the study. The apparent digestibility of DM, CP and GE were measured over a 96 hour total faecal collection from days 18-21. At 12 hourly intervals faecal material from each weanling was collected, weighed, and a subsample was taken and frozen at -20°C. One kilogram samples of the feed were collected and frozen at -20°C on days 18 and 21. After faecal subsamples were freeze dried and ground, two gram subsamples from each 12 hour collection period from each weanling were pooled to create representative 24, 48, 72 and 96 hour samples.

Voluntary feed intake of the weanlings was stable during days 6-21, and the weanlings consumed 7.69 (±0.07) kg/DM/day of the ensiled lucerne and cracked maize feed over the 16 day period. On days 6, 13 and 21 when body weight was measured, the weanlings consumed a mean of 94.57 (±1.43) g DM/kg $BW^{0.75}$ or 2.20% (± 0.34) of body weight per day on a DM basis. The feed contained 53.96% (±0.72) DM, and 13.22% (±0.10), CP and 12.47 MJ/kg (±0.01) GE on a DM basis. The apparent DM, CP and GE digestibility of the ensiled lucerne and cracked maize feed was 70.55% (±0.40), 62.39% (±0.60) and 68.51% (±0.43), respectively. The consistency of the apparent digestibility measures of DM% CP% and GE% were not significantly affected by the duration of total faecal collection during the apparent digestibility study (p=0.982, p=0.984, and

p=0.312, respectively). However, as the duration of the apparent digestibility study increased, the variability within measurements of DM, CP, and GE decreased.

This study indicated that Thoroughbred weanling horses have a low VFI of the ensiled lucerne and cracked maize feed in comparison to other studies. However, the apparent digestibility of DM, CP and GE of this feed were similar to other studies. This study also indicated that 12 hours of total faecal collection is sufficient to determine DM, CP and GE apparent digestibility.

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3.2 INTRODUCTION

Lucerne (*Medicago sativa*), also known as alfalfa, is a popular forage for feeding horses (NRC, 1989; Small, 1996; Crozier *et al.*, 1997). Lucerne is higher in protein, vitamins and some minerals than grasses (NRC, 1989), and is suitable to feed to horses of all ages and stages of production (NRC, 1989; Crozier *et al.*, 1997). Lucerne hay is preferred by horses to grass hays (Cymbaluk, 1990; LaCasha *et al.*, 1999; Rodiek and Jones, 2012), and horses will consume more of lucerne than grass hay (Cuddeford, 2013). It has been suggested that the reason for this is that the dry matter (DM) digestibility of legume hays is significantly higher than grass hays (Crozier *et al.*, 1997).

Forage can be conserved by drying as hay, chopped as chaff, ground, pelleted, cubed, and wafered or it can be conserved through ensiling. Ensiled forages are preserved through the anaerobic fermentation of non-structural carbohydrates (NRC, 2007a).

When pasture is limited or unavailable, grass hay is traditionally the most common conserved forage that is offered to horses (Moore-Colyer and Longland, 2000; Bergero and Peiretti, 2011). However, in recent years ensiled grasses have become more widespread as an alternative forage to hay in the horse sector (Hale and Moore-Colyer, 2001; Peiretti and Bergero, 2004; Müller, 2005; Bergero and Peiretti, 2011), especially when hay quality may be compromised due to unstable weather conditions during the haymaking season (Peiretti and Bergero, 2004; Bergero and Peiretti, 2011). Ensiled forages have a higher nutritive value than corresponding hays (Hale and Moore-Colyer, 2001; Bergero and Peiretti, 2011), as they are harvested at an earlier stage of maturity than hay (Peiretti and Bergero, 2004; Connysson *et al.*, 2006; Ragnarsson and Lindberg, 2008), and have a high digestibility (Coenen *et al.*, 2003). Feeding ensiled forages can reduce the level of dust particles (Moore-Colyer and Longland, 2000; Peiretti and Bergero, 2004; Müller, 2005; Bergero and Peiretti, 2011), and allergens that stabled horses in particular are exposed to (Vandenput *et al.*, 1997, Coenen *et al.*, 2003).

Ensiled forages have previously been fed to horses with caution due to concerns of microbial contamination with *Clostridia* spp. or *Listeria* spp. However, there is often insufficient moisture in high DM (40-60% DM) ensiled forages for proliferation of these microbial organisms (NRC, 2007a). Provided that ensiled forages are conserved correctly, and they maintain a similar nutritive value to the original grass, they do not pose a risk to horse health and they are a valid alternative to hay (Peiretti and Bergero, 2004). Anecdotal evidences suggest that ensiled grass forages are being fed to horses by an increasing number of horse owners with no detrimental effects (Moore-Colyer and Longland, 2000).

As smaller hermetically sealed bales of forage appear on the market (Bergero *et al.*, 2002), the interest in feeding ensiled forages has increased, particularly with horse owners who have a small number of horses to feed (Müller, 2005, Müller *et al.*, 2007). The smaller bale size allows ensiled forages to be consumed quickly after opening to prevent aerobic deterioration (Peiretti and Bergero, 2004).

The voluntary feed intake (VFI) of ensiled forages by horses is largely influenced by forage type and the DM content. Horses tend to have larger intakes of high DM (40-65% DM) ensiled forages than low DM (<30% DM) ensiled forages (NRC, 2007a; Cuddeford, 2013). Most studies of ensiled forage intakes have been conducted using ponies, and large variations in VFI have been reported on a metabolic body weight basis (g DM/kg $BW^{0.75}$), ranging from 39 units in clamp grass silage to 85-98 units in small baled rye-grass haylage (Moore-Colyer and Longland, 2000; Hale and Moore-Colyer, 2001; Bergero et al., 2002; Bergero and Peiretti, 2011).

Cereal grains are commonly added to feed rations to increase the dietary energy, since most young horses require more energy and protein than forage can provide alone (Moore-Colyer and Longland, 2000; Connysson *et al.*, 2006; Brown-Douglas, 2012). However, there is a growing interest in high-energy, fibre-based feeds as an alternative to providing dietary energy through grain (Murray *et al.*, 2005). Energy dense fibrous feeds support the normal function of the hind gut and may reduce digestive problems (Miraglia *et al.*, 2006; Willing *et al.*, 2009), while the risk of developmental orthopaedic disorder may be decreased by feeding young horses low starch diets (Miraglia *et al.*, 2006).

There are few data published on voluntary feed intake and apparent digestibility of feed in weanling horses, and none on feeding horses an ensiled lucerne and cracked maize feed. The aim of this study was to determine the VFI and apparent DM, CP and

GE digestibility of an ensiled lucerne and cracked maize feed in Thoroughbred weanling horses. An additional aim was to determine the minimum duration of total faecal collection required to ensure consistent measurements of DM, CP and GE apparent digestibility.

3.3 METHODS AND MATERIALS

Voluntary feed intake and apparent digestibility experiments were conducted concurrently over 21 days from the 18th October to the 8th November 2012. Voluntary feed intake was measured for 16 days from day 6 to day 21, and apparent digestibility for four days from day 18 to day 21.

3.3.1 Animals

Six healthy Thoroughbred weanling filly horses (*Equus caballus*) were used to measure voluntary feed intake (VFI) and apparent digestibility of an ensiled lucerne and cracked maize feed (FiberSure®, Fiber Fresh Feeds, Ltd, Reporoa, NZ). The weanlings (362 ± 10 days old; 339.5 ± 11.2 kg BW) were all progeny of the same sire and had been reared as one cohort. These weanlings were previously used in a growth study (See Chapter 2) and were transported 30 km on day 0 of the study from Newmarket Lodge Stud (Manawatu, New Zealand) to the LWT Animal Nutrition Ltd facilities (Manawatu, New Zealand). All weanlings were identified using their unique Thoroughbred brands. Prior to the start of the trial (day 0), all weanlings were treated with an oral anthelmintic (UltraMox Wormer, Bomac Laboratories Ltd., Auckland, New Zealand) at 5 g/100 kg bodyweight.

3.3.2 Management

The weanlings were housed in individual loose-boxes (4 x 4 m), lined with rubber matting at LWT Animal Nutrition Ltd., Kiwitea, Feilding (figure 3.1). The six loose-boxes were in one row; the walls consisted of a wooden lower half and an upper half of mesh, allowing horses to have visual contact with all other horses in the loose-boxes and yard. An automatic watering system was available in each loose-box. A thin layer of wood shavings was placed on the rubber matting during the adaptation and VFI assessment periods to absorb urine and prevent the weanlings from slipping while they adapted to the rubber flooring. The wood shavings were removed and the rubber was thoroughly cleaned before the apparent digestibility phase of the study was carried out. The weanlings were turned out on to a compact earth yard for 30 minutes twice a day in pairs for free exercise. The weanlings were fed at 08:00 and 20:00 hours immediately after the loose boxes had been cleaned during both the VFI and apparent digestibility studies.

Figure 3.1 Loose-box facilities that the weanlings were housed in during the VFI and digestibility study.

3.3.3 Measurements

At weekly intervals, the body weight and wither heights of all weanlings were measured, and body condition score was assessed. Bodyweight was recorded to the nearest 0.5 kg using electronic scales (Tru-test 703, True test, Auckland, New Zealand), positioned on a level surface within a loose box. The scales were re-calibrated before each weekly weighing with a known weight. Wither height was recorded at the highest point of the wither using a commercial spirit level measuring stick, while the weanling was positioned standing on a level ground surface within the loose box. Body condition scores were assessed throughout the study using a modified version of the Henneke *et al.* (1983) 9 point scale, where half scores were given to animals that clearly did not fit into the whole number categories.

3.3.4 Diet

Prior to the VFI study, all weanlings were kept on pasture and received the commercial ensiled lucerne (*Medicago sativa*) and cracked maize (*Zea mays*) feed used in the current study as a supplement. The feed (FiberSure™, Fiber Fresh Feeds, Reporoa, New Zealand) consisted of approximately 65% lucerne, 35% cracked maize and 5% vitamin and mineral premix with molasses and was available in 25 kg hermetically sealed bags. The weanlings were offered this diet as the sole source of nutrition in the current study. Table 3.1 provides the nutrient analysis of the feed offered to the weanlings.

Table 3.1 Dry matter content and nutrient composition of the ensiled lucerne and cracked maize feed (as provided by the manufacturer) on a DM basis that was provided to the Thoroughbred weanling fillies.

Analysis	Amount
Dry matter, %	59.30
Crude protein, g/kg DM	117.00
Crude fibre, g/kg DM	148.00
Crude fat, g/kg DM	30.00
Calcium, g/kg DM	10.00
Phosphorus, g/kg DM	5.20
Selenium, mg/kg DM	0.27
Digestible energy, MJ/kg	11.98

3.3.5 Voluntary feed intake

Following five days of adaptation to the loose-boxes, VFI of the ensiled lucerne and cracked maize feed by weanling horses was measured for 16 days, from 8:00 hours on day 6 until 8:00 hours on day 22 (day 21 of collection) during the adaptation phase of the apparent digestibility, and during the apparent digestibility study itself.

The weanlings were offered the feed at an initial rate of approximately 3.2% DM of body weight (after Ordakowski-Burk *et al.*, 2006). This feeding level was adjusted to ensure that the weanlings had 2 kg of feed remaining at the end of each feeding period. If the refusal was less than 2 kg, the volume of feed offered was then increased. The feed was weighed on scales (Metter Toledo Inc, Columbus, OH, USA, model number SB32000), prior to being offered to the horses, and all refused feed from previous meal was collected immediately before the next feeding period, weighed, recorded and then discarded. The weight of the refused feed was used to calculate the actual intake in each 12 hour period.

Figure 3.2 (a) Rubber feed bin containing the ensiled lucerne and cracked maize feed that was offered to the weanlings during the VFI and apparent digestibility studies. (b) A filly eating the feed from the rubber feed bin during the VFI study. Wood shavings were scattered on the rubber flooring during the VFI to absorb moisture from urine and faeces and prevent slipping.

3.3.6 Apparent Digestibility

The apparent digestibility collection began on day 18 of the study. Each weanling was maintained at the same feeding level that was established during the VFI study. Total apparent digestibility collection was conducted over 96 hours from 08:00 hours on day 18 to 08:00 hours on day 22 (day 21 of collection). One kilogram subsample of the feed was collected and frozen at -20°C on days 18 and 21. From 08:00 to 20:00 hours faeces were collected every hour into individual 72-L plastic containers with air-tight fitted lids (figure 3.3).

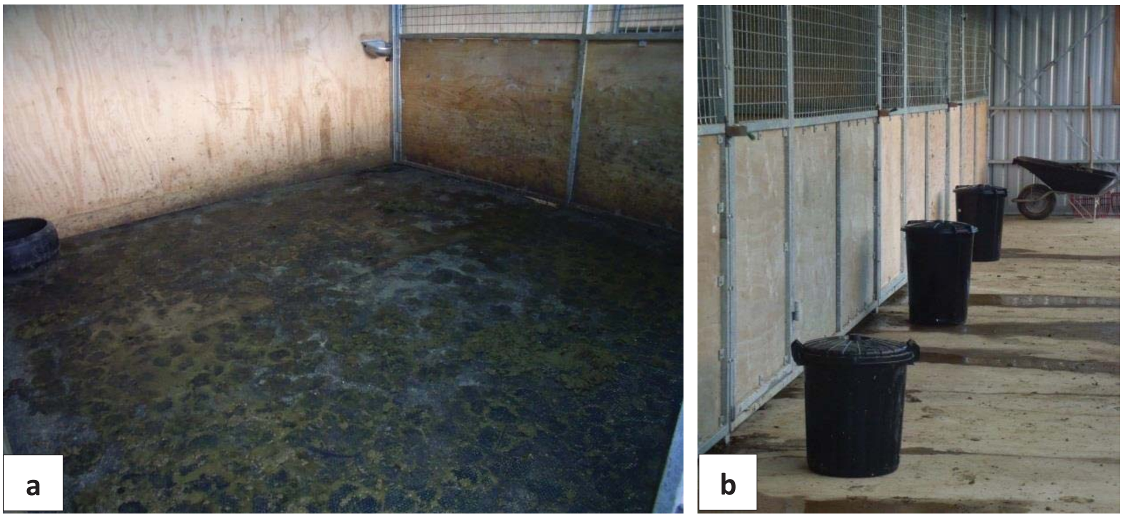

Figure 3.3 (a) An example of a loose box that the weanlings were housed individually in during the VFI and digestibility study. (b) Plastic containers with lids that faeces were collected into and stored during the digestibility study.

The faecal material produced from 20:00 to 08:00 hours was collected at 08:00 hours and stored in the individual plastic containers. The faeces produced by each weanling were collected every 12 hours and weighed to determine total faecal output. The faeces were then mixed and subsamples from each weaning were taken and frozen at -20°C. The remaining faeces were discarded from the plastic containers. Faecal subsamples were collected in decreasing amounts over the 96 hour collection (the volume of faecal sub-sample collected every 12 hours are shown in table 3.2) to minimise the volume required for freeze drying while ensuring that the faecal subsample volumes collected at the beginning of the apparent digestibility study were still large enough to make up the final representative pooled samples. At 12 hourly intervals (08:00 and 20:00 hours), refused feed from each animal was collected, weighed and recorded.

Table 3.2 Wet weight (g) of faecal sub-samples that were collected at 12 hourly intervals during the apparent digestibility study.

	Hour of apparent digestibility							
	12h	24h	36h	48h	60h	72h	84h	96h
Subsample (g)	900	800	700	600	500	300	200	100

Faecal samples were freeze dried and ground through a 1 mm sieve (Ultra centrifugal mill (ZM-100, Retsch GmbH & Co., Hann, Germany). Once the faecal samples were ground, two grams faecal subsamples from different 12 hour collection periods per weanling were pooled into 24, 48, 72 and 96 hour samples.

Five faecal samples from each weanling (representing 12, 24, 48, 72, and 96 hour collection) and one mixed sample (days 18 and 21) of the ensiled lucerne and cracked maize feed fed in the trial were analysed at the Nutrition Laboratory (Institute of Food, Nutrition & Human Health, Massey University, Palmerston North), for DM, CP and GE. Dry matter content was measured by drying samples in a convection oven at 105^{o}C (WATVIC, Wellington, NZ). Total nitrogen (N) was determined by the Dumas method (Dumas, 1831) (Leco CNS 2000 Model 602 600 200) and was converted to CP by multiplying N x 6.25 (AOAC 968.06). The GE content was determined through heat of combustion using an adiabatic bomb calorimeter (Gallenkamp Autobomb).

3.3.7 Statistical analysis

The effect of day on the VFI of the weanlings was determined using a one-way ANOVA. A post-hoc pairwise comparison was performed using the bonferroni method in a one-way ANOVA to determine the difference in the duration of faecal collections for determining DM, CP and GE apparent digestibility. Statistical analyses were performed using Stata 8 software (StataCorp LP, College Station, TX, USA). Parametric data is presented as mean ± SE and non-parametric data is presented as median ± IQR. A significance level of $p<0.05$ was set for all tests.

3.3.8 Animal ethics

This study was conducted with approval (protocol number 12-51) from the Massey University Animal Ethics Committee (MUAEC), Palmerston North, New Zealand.

3.4 RESULTS

3.4.1 Animal health

All weanlings remained healthy throughout this study. Weanling #7 received penicillin (20 ml) on days 20 and 21 to treat localised swelling around a wound on the left forelimb resulting from a kick during exercise in the compact earth yard. The wound was also treated with a topical antiseptic cream.

3.4.2 Average daily gain

The weanlings experienced an initial mean body weight loss over days 0-6 of -0.36 (±0.39) kg/day as they recovered from the stress of being transported and adjusted to being stalled individually in new facilities with different management. From days 6-21 the average daily gain (ADG) increased to 0.78 (±0.20) kg/day. The weekly mean body weight, wither height and median body condition scores are shown in table 3.3.

Table 3.3 Body weight (kg), wither height (cm) (mean ± SE) and body condition score (modified from Henneke *et al.*, 1983) (median ± IQR) of Thoroughbred weanling fillies stalled during voluntary feed intake and apparent digestibility study.

Days of trial	Body weight	Wither height	Body condition score
0	339.5 ± 11.2	145.0 ± 1.3	5.8 ± 6.0-5.5
6	337.3 ± 10.2	145.0 ± 1.3	6.0 ± 6.0-5.0
13	343.0 ± 8.2	145.1 ± 1.4	5.8 ± 6.0-5.5
21	349.0 ± 10.2	145.6 ± 1.1	5.8 ± 6.0-5.5

3.4.3 Voluntary feed intake

The VFI of the weanlings was highly variable from days 1-5 with a mean VFI of 6.73 (±0.23) kg/DM/day (range 3.63-8.74 kg/DM/day), as they recovered from being transported and adapted to their new environment. There was a significant effect of day on VFI (kg/DM/day) during days 1-5 (p=0.010).

The feed intake during the apparent digestibility period of the study was also included in the VFI data as the weanlings continued to be fed at the same level as the VFI period and the collection of faeces throughout the day did not appear to affect the VFI of the weanlings. The weanlings consumed a mean VFI of 7.69 (±0.07) kg/day on a DM basis over 16 days (day 6-21). The VFI was stable from days 6-21, and there was no effect of day on VFI (kg/DM/day) during days 6-21 (p=0.845). The ambient temperature appeared to have a small influence on daily VFI (R^2=0.28), the maximum and minimum ambient temperatures ranged from 12-21°C and 5-14°C, respectively during the 16 days of VFI. The mean VFI that was consumed by the weanlings over the 16 days equates to 94.77 (±0.95) MJ/day of digestible energy and 628.17 (±8.54) g/day of CP.

During this study, the body weights of the weanling horses were only measured on four occasions, day 0, 6, 13 and 21. Due to the daily changes in the body weight of the weanling horses that occurred as a result of growth, VFI could only be accurately standardised to g DM/kg of metabolic body weight or percentage of body weight on three days, day 6, 13 and 21. The mean VFI of these three days are 94.57 (±1.43) g DM/kg $BW^{0.75}$, and 2.20 (±0.34) % of body weight.

The VFI per day of the weanling horses is shown in table 3.4 as kg DM/day (days 6-21) (mean ± SE), metabolic body weight (g DM/kg $BW^{0.75}$) (on days 6, 13 and 21), and body weight percentage, (on days 6, 13 and 21) (mean ± SE). The VFI of the weanlings from days 1-21 is presented as kg/day (mean ± SE) in figure 3.4, and days 6, 13, 21 as g DM/kg of metabolic BW (mean ± SE) in figure 3.5, and as a percentage of body weight per day (mean ± SE) in figure 3.6. The ADG of the six Thoroughbred weanlings at day 6, 13 and 21 (mean ± SE) is shown in figure 3.7. No VFI data could collected from weanling #8 on day 5 of the study as the refused feed was mixed with the wood shavings, and was therefore unable to be weighed accurately.

Table 3.4 Voluntary feed intake (VFI) of an ensiled lucerne and maize feed on a DM basis (mean ± SE) as kg/day, g/kg of metabolic body weight, and as percentage of body weight by Thoroughbred weanlings on days 6, 13 and 21 of the study, and mean VFI over 16 days from day 6 to day 21 (kg/day) and mean VFI of days 6, 13 and 21 (g DM/kg of metabolic body weight, and percentage of body weight).

VFI	Day 6	Day 13	Day 21	Mean ± SE
kg DM/day	7.43 ± 0.28	7.42 ± 0.20	7.76 ± 0.24	7.69 ± 0.07
g DM/kg BW $^{0.75}$	94.47 ± 3.23	93.10 ± 2.16	96.14 ± 2.19	94.57 ± 1.43
% BW	2.20 ± 0.08	2.16 ± 0.05	2.22 ± 0.05	2.20 ± 0.34

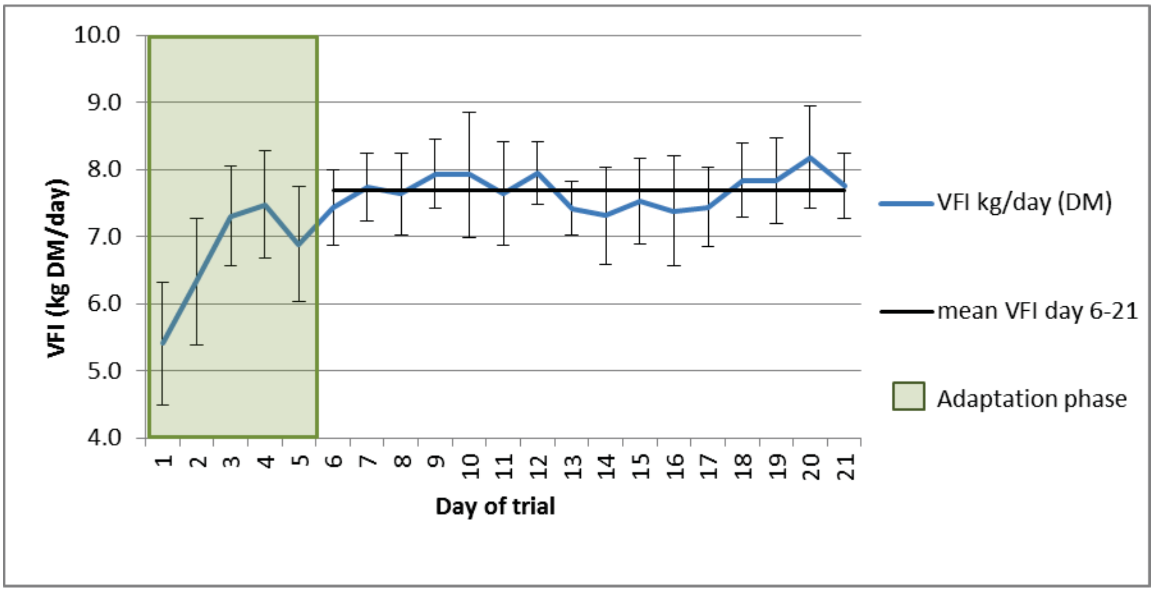

Figure 3.4 Voluntary feed intake (kg DM/day) of the ensiled lucerne and cracked maize feed by six Thoroughbred weanling horses (mean ± SE) over the 21 days of the study. The adaptation phase from day 1-5 is highlighted and the mean VFI from day 6-21 is shown as a black line.

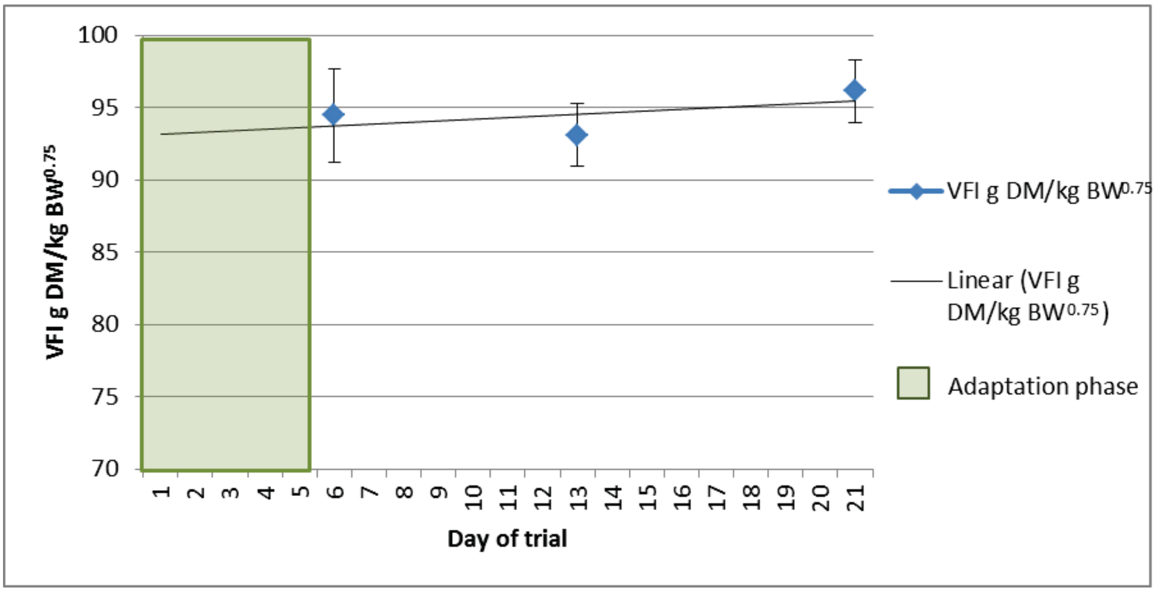

Figure 3.5 Voluntary feed intake (g DM/kg BW$^{0.75}$) of an ensiled lucerne and cracked maize feed by six Thoroughbred weanling horses (mean ± SE) on days 6, 13 and 21 of the study, with a linear line fitted. The adaptation phase from day 1-5 is highlighted.

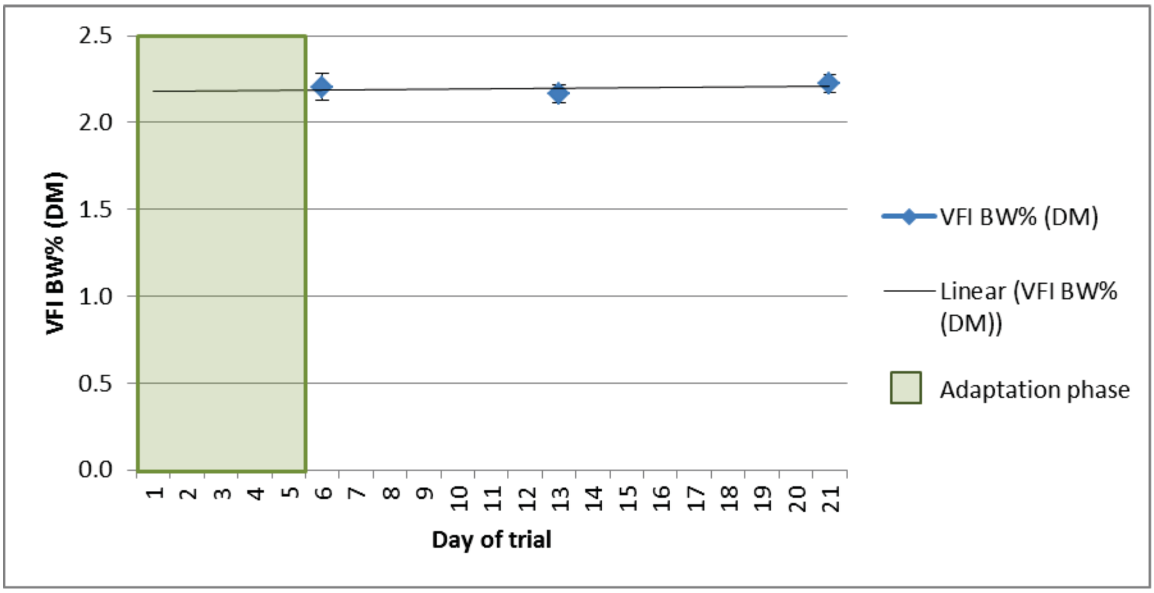

Figure 3.6 Voluntary feed intake (on a DM basis) of an ensiled lucerne and cracked maize feed as a percentage of body weight per day by six Thoroughbred weanling horses (mean ± SE) on days 6, 13 and 21 of the study, with a linear line fitted. The adaptation phase from day 1-5 is highlighted.

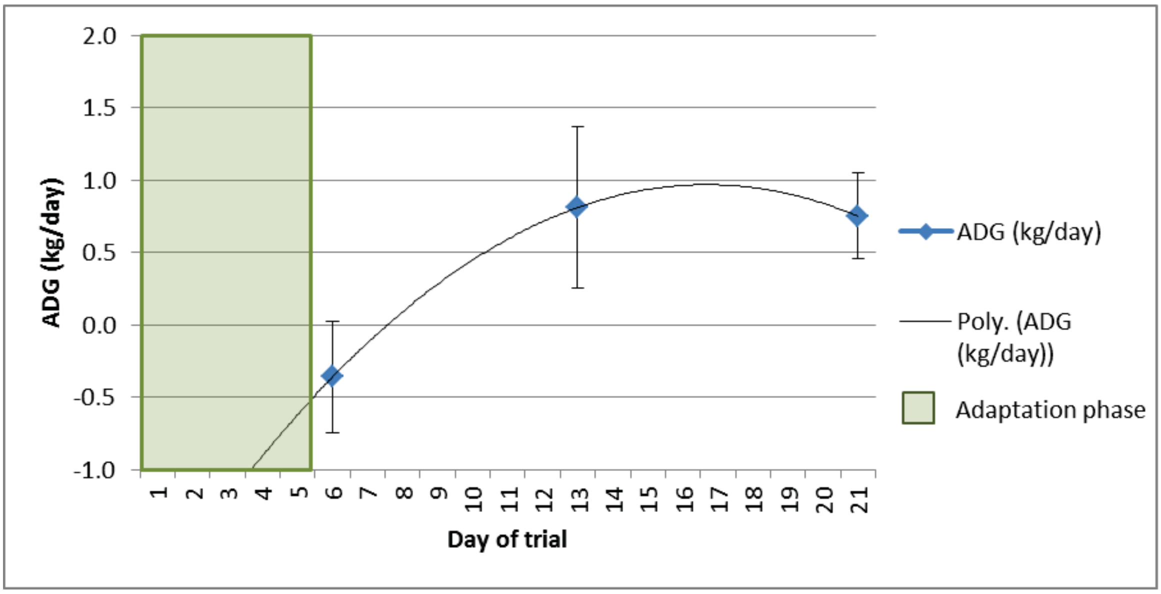

Figure 3.7 ADG (kg/day) of six Thoroughbred weanling horses (mean ± SE) on days 6, 13 and 21 of the study, with a second degree polynomial curve. The adaptation phase from day 1-5 is highlighted.

3.4.4 Apparent digestibility

The ensiled lucerne and cracked maize feed consisted of 53.96% (±0.72) DM, and 13.22% (±0.10) CP and 12.47 MJ/kg DM (±0.01) GE. The apparent DM, CP and GE digestibility of the ensiled lucerne and cracked maize feed on a DM basis was 70.55% (±0.40), 62.39% (±0.06), and 68.51% (±0.43), respectively (table 3.5).

The consistency of the apparent digestibility measures of DM%, CP%, and GE% were not significantly affected by duration of total faecal collection over during the apparent digestibility study, ($p=0.982$, $p=0.984$ and $p=0.312$, respectively: figure 3.8). The mean apparent digestibility of DM, CP, and GE ranged from 70.06% (range: 66.07-72.99), 62.01% (range: 54.16-67.08), and 66.61% (range: 62.51-69.63) at 12 hours, respectively to 70.56% (range: 67.71-73.31), 62.12% (range: 59.51-65.69), and 69.18% (range: 67.09-69.97) at 96 hours, respectively.

Table 3.5. The mean ±SE content of dry matter (%), crude protein (% DM) and gross energy (MJ/kg DM) and digestibility coefficients of DM, crude protein and energy of an ensiled lucerne and cracked maize feed fed to Thoroughbred weanling horses, pending 96 hours.

	Composition of ensiled lucerne and cracked maize feed	**Apparent digestibility coefficient**
Dry matter %	53.96 ± 0.72	70.55 ± 0.40
Crude protein %	13.22 ± 0.10	62.40 ± 0.60
Gross Energy MJ/kg DM	12.47 ± 0.01	68.51 ± 0.43

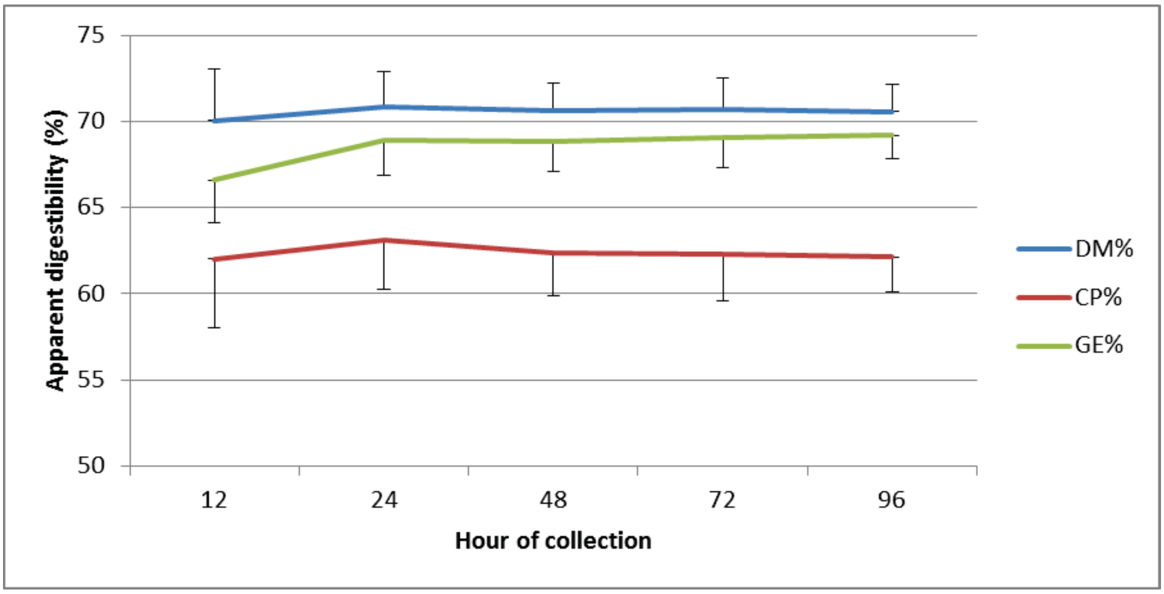

Figure 3.8 Mean ±SE of the apparent digestibility coefficient of dry matter (%), crude protein (%) and energy (%) of ensiled lucerne and cracked maize feed determined at 12, 24, 48, 72 and 96 hours from six Thoroughbred weanlings.

3.5 DISCUSSION

3.5.1 Voluntary feed intake

The weanling horses used in this VFI and digestibility study had been used in a growth study (See Chapter 2) that had ended one day prior to this study beginning. During that growth study the weanlings where they were kept on pasture and supplemented with the same ensiled lucerne and cracked maize feed that was used in this study. Thus, the horses were accustomed to eating this feed prior to the VFI and digestibility study commencing, but they were not fed this feed exclusively until day 1 of the current VFI and digestibility study. The weanlings showed an inconsistent and low VFI during the first five days of the current study and consequently a low ADG (-0.36) between days 0-6. This is most likely attributed to the effect of stress during transportation (30 km) between the stud farm that the weanlings were kept at during the growth study (See Chapter 2), and the facility used for the current VFI and digestibility study, as well as adaption to the new facilities and housing in loose-boxes. Despite the change in facilities and management, the weanling horses remained in their weaning cohort and were able to have visual contact with each other throughout the VFI and digestibility study. Transportation is known to induce stress in animals (von Borell, 2001), likewise, individual stabling of horses is also known to induce stress in young horses, particularly during the first time that they are stabled (Harewood and McGowan, 2005; Visser *et al.*, 2008). Individual stabling represents a social challenge for horses as they tend to seek out contact with their paddock or stable mates (Heleski *et al.*, 2002). In one study, individually stabled horses were more vigilant than pair stabled horses during the first three weeks of being stabled. The pair stabled horses in that study displayed fewer stress-related behaviours (neighing, pawing, snorting and nibbling), and had higher weight gains than individually stabled horses (Visser *et al.*, 2008). Horses affected by the stress of sudden environmental changes can reduce their VFI and consequently their body weight (Ralston, 1986; Kiley-Worthington, 1987). The lower VFI during days 1-5 along with the low ADG from day 0-6 appear to be indirect measures of the underlying stress that the weanlings experienced associated with transportation and novel facilities and management. Due to the lower VFI during days 1-5 (figure 3.4), and the loss of body weight that occurred to the weanlings during the first six days of the current study (figure 3.7), days 1-5 were considered as a period of adaptation.

The 16 day duration of the VFI study was used to ensure that the VFI data was truly representative of intake, as previous studies have suggested that eight to ten days are normally required for maximum VFI to be attained (Darlington and Hershberger, 1968), and 15 days are required for VFI to stabilise (Silva *et al.*, 2012). In the current study, there was a significant effect of day on VFI of the weanling horses during the adaptation period of days 1-5. However, there was no effect of day on VFI of the weanlings during days 6-21, the period over which VFI was eventually assessed. This is in contrast to other studies that reported an effect of day on the variability of VFI measurements of mature horses (Ordakowski-Burk *et al.*, 2006; Staniar *et al.*, 2010). This may indicate that the weanlings in the current study were well adapted to consuming the ensiled lucerne and cracked maize feed prior to the VFI and apparent digestibility study commencing. The weanlings had a mean ADG of 0.78 kg/day from days 6-21, which is slightly higher than the 0.63 kg/day ADG reported for pasture fed Thoroughbred weanlings of a similar age in New Zealand (Grace *et al.*, 2003). It is possible though that the weanlings in the current study may have compensated during days 6-21 for the loss of body weight (-0.36 kg/day) that occurred during days 0-6. The weanlings achieved a steady VFI and ADG from days 6-21; however, a slight non-significant decrease in VFI was evident from days 13-17, which may partially support this idea.

While the daily ambient temperature at the VFI and digestibility facilities was not recorded, accessing weather data from Accuweather (AccuWeather, 2013) indicated that the local ambient temperature may have had a subtle influence on VFI (NRC, 2007a). The mean ambient maximum temperatures in the locality of the facility were higher (17.8°C) during days 13-17 when VFI was slightly lower in comparison to days 6-12 (15.7°C) and days 18-21 (13.3°C) when the ambient temperatures were lower and the VFI was higher. This is consistent with a study where the VFI of growing pigs was found to decrease significantly from 2.40 to 1.82 kg/day as ambient temperature increased from 19 to 29°C (Quiniou *et al.*, 2000).

Voluntary feed intake can be standardised between animals of different body sizes by considering it as a percentage of body weight, or g DM/kg of metabolic body weight ($BW^{0.75}$) (Kleiber, 1947). However, as the body weight of the weanling horses used in the current study was constantly changing, and they were only weighed on days 6, 13 and 21 during the study, the VFI can only be accurately standardised as g DM/kg of metabolic body weight or as a percentage of body weight on those three days (day 6, 13 and 21). The means of these three days are used to compare VFI as g DM/kg of metabolic body weight and as a percentage of body weight with other studies.

In the current study, the mean VFI of the ensiled lucerne and cracked maize feed (on a DM basis) by the weanling horses was 2.20% of body weight (from data collected on day 6, 13 and 21). This is similar to yearling horses consuming Coastal Bermuda grass hay at 2.5% (DM) of body weight (Aiken *et al.*, 1989), and to yearling Quarter Horses fed Tall Fescue grass (2.5% BW DM), and Caucasian Bluestem grass (2.3% BW DM) (LaCasha *et al.*, 1999). It is also similar to six month old Thoroughbred weanling colts (252 kg body weight) who consumed 2.29% of body weight (DM) of a mixed diet of lucerne cubes and oat-based concentrate (Earing, 2011). The VFI in the current study was slightly lower than the 3.1% of body weight (DM) reported for seven month old Mangalarga Marchador weanling horses fed 60% lucerne hay and 40% concentrates (Silva *et al.*, 2012), and yearling Quarter Horses fed lucerne hay (LaCasha *et al.*, 1999). It was also slightly lower than the 2.8% of body weight (DM) of lucerne hay consumed by Arabian geldings (2-6 years old) (Crozier *et al.*, 1997).

Few studies have been carried out investigating the VFI of weanling horses, most likely because of the risk that over nutrition may increase growth disorders in them. Young, growing horses have been reported to have a higher VFI than mature horses, which is thought to be related to the higher energy requirements that young horses have for growth (Aiken *et al.*, 1989). Yearling horses consumed 0.5% of body weight more of Coastal Bermuda hay on a dry matter basis, than mature horses (Aiken *et al.*, 1989), and similarly six month old Thoroughbred weanling colts consumed 0.41% of body weight more of a mixed diet of lucerne cubes and oat-based concentrate on a DM basis, than mature gelding horses (Thoroughbred, Standardbred and Quarter Horse) in another study (Earing, 2011).

The mean VFI of the Thoroughbred weanlings (from day 6, 13 and 21) in the current study was 94.57 g DM/kg BW$^{0.75}$ when VFI was considered on a metabolic body weight basis. This is similar to the VFI of 10 month old heavy breed weanling colts fed grass hay (99.1 g DM/kg BW$^{0.75}$) or grass hay and 30% concentrate (ground maize, ground barley and ground nut meal) (99.4 g DM/kg BW$^{0.75}$) or 60% of the same concentrate (92.3 g DM/kg BW$^{0.75}$) of the diet (Martin-Rosset and Dulphy, 1987). As already mentioned, a higher VFI of lucerne hay was reported for Quarter Horse yearlings (134.0 g DM/kg BW$^{0.75}$) (LaCasha *et al.*, 1999), and Arabian geldings (2-6 years old) (122 g DM/kg BW$^{0.75}$) (Crozier *et al.*, 1997). While VFI is often reported on a metabolic body weight basis to standardise horse body size, differences may still occur between different horse breeds on a metabolic body weight basis. One study that compared VFI of dehydrate lucerne and oat straw diets between mature Thoroughbred horses, Highland ponies and young Shetland ponies (1-2 years old) on a metabolic body weight basis, found that the Thoroughbred horses consumed significantly more feed (58.5 g DM/kg BW$^{0.75}$) than the Highland ponies (52.3 g DM/kg BW$^{0.75}$), who in turn consumed significantly more than the Shetland ponies (45.6 g DM/kg BW$^{0.75}$) (Cuddeford *et al.*, 1995).

The range of VFI reported for grass hays in mature ponies (63-87 g DM/kg BW$^{0.75}$) (Moore-Colyer and Longland, 2000; Bergero and Peiretti, 2011) is lower than the range of VFI of grass hays in mature horses (72-111 g DM/kg BW$^{0.75}$) (Ordakowski-Burk *et al.*, 2006; Staniar *et al.*, 2010) and lucerne hays (122-134 g DM/kg BW$^{0.75}$) (Crozier *et al.*, 1997; LaCasha *et al.*, 1999) and the ensiled lucerne and cracked maize feed in the current study (range 84-107. g DM/kg BW$^{0.75}$ (days 6, 13, 21)).

The mean VFI of the ensiled lucerne and cracked maize feed (from day 6, 13 and 21) in the current study by Thoroughbred weanling horses (95 g DM/kg BW$^{0.75}$) was similar to the VFI of grass haylage by mature ponies (85-98 g DM/kg BW$^{0.75}$) (Bergero *et al.*, 2002). A large range (39-98 g DM/kg BW$^{0.75}$) of VFI has been reported for ensiled grasses in mature ponies (Moore-Colyer and Longland, 2000; Hale and Moore-Colyer, 2001; Bergero *et al.*, 2002; Bergero and Peiretti, 2011). These differences may be related to the original forage nutritive value, DM content and/or conservation method.

Prior to the current study, the same weanlings were kept on pasture (See Chapter 2) and their feeding behaviour was monitored for 30 minutes before a supplementary feed (the same ensiled lucerne and cracked maize feed used in the current study) was offered and two hours post-feeding (Shotton, 2013). The weanlings showed a preference for eating pasture over the ensiled supplementary feed during the two hour post-feeding period which was monitored on 15 occasions. Following an increase in feeding level the weanlings did not consume all of the supplementary feed that offered to them over a 24 hour period on 14 occasions (over 61 days). This suggested that the ensiled lucerne and cracked maize feed was not as palatable as the pasture (Shotton, 2013). In the current study, the palatability of the ensiled lucerne and cracked maize feed may have contributed to the VFI being lower than previously reported in young horses (LaCasha *et al.*, 1999; Silva *et al.*, 2012). Ensiled forages generally have a higher GE value than substrates (Muhonen *et al.*, 2008), and it has been suggested that lower quantities of energy dense ensiled forages can be fed to meet energy requirements (Ragnarsson and Lindberg, 2010), which is in agreement with one study where horses consumed more hay than silage (McLean *et al.*, 1995). However, other studies have observed horses and ponies consuming higher quantities of ensiled forages than hay on a DM basis (Moore-Colyer *et al.*, 2003; Muhonen *et al.*, 2008).

Grass silages with a high DM (40-65% DM) are more palatable than low DM (<30% DM) grass silages (NRC, 2007a), and horses will generally consume more ensiled forages of a high DM than of a low DM (Cuddeford, 2013). However, the preference of silage over high and low DM haylages and hay by horses in one study was unable to be explained by the authors (Müller and Udén, 2007). The digestibility of ensiled grasses is often higher than that of grass hays (Coenen *et al.*, 2003; Moore-Colyer *et al.*, 2003). However, the quality of conserved forage reflects the original source (NRC, 2007a), and the VFI of ensiled forages by horses is largely dependent upon the type of forage that is used. Horses generally consume more legume forages than grass-based forages as hays and ensiled forages (Van Soest, 1965; Cuddeford, 2013), and lucerne hay was preferred over grass hays in a preference test by yearling Quarter Horses (LaCasha *et al.*, 1999). This preference for legumes has been shown in numerous studies, with horses and ponies having a larger intake of red clover hay (Fonnesbeck *et al.*, 1967), red clover silage (Hale and Moore-Colyer, 2001) and lucerne hay than grass hay (Fonnesbeck *et al.*, 1967; Crozier *et al.*, 1997; LaCasha *et al.*, 1999) or silage (Hale and Moore-Colyer, 2001).

The method of conservation can affect the DM content and the quality of the ensiled forage, and subsequent preference and VFI by horses (Peiretti and Bergero, 2004; Müller and Udén, 2007). Voluntary feed intake can also be affected by the physical form of the feed (Cuddeford, 2013), and in one study, ponies were found to have slight preference for chopped baled grass silage over un-chopped baled grass silage (Moore-Colyer *et al.*, 2003). In the current study, the lucerne that was used in the ensiled lucerne and cracked maize feed was chopped prior to being ensiled. However, since no VFI study was performed with equivalent feed made of un-chopped lucerne, it is unknown if chopping had an influence on the VFI of this feed.

In the current study, the weanlings consumed approximately 94.77 MJ/day of digestible energy, which is higher than reported for yearling horses (76.2 MJ/day) (Aiken *et al.*, 1989), and 21% higher than the current NRC recommendations. The weanlings in this study also consumed 634 g/day of digestible CP, which is 25% lower than the current NRC recommendations for weanlings of their age and weight (NRC, 2007a). The energy and crude protein requirements for the weanlings in this trial were calculated using the NRC (2007b) for the mean body weight of the six weanlings at day 0.

3.5.2 Apparent digestibility

The total faecal collection period of apparent digestibility studies in the horse has been reported to range from three (Staniar *et al.*, 2010), to seven days (Darlington and Hershberger, 1968). In the current study, the total faecal collection was carried out in discrete 12 hour periods for 96 hours, and ground faecal freeze-dried subsamples were submitted for laboratory analysis in pooled samples of 24, 48, 72, and 96 hours of collection to determine the duration of total faecal collection that is required to obtain consistent measures of apparent digestibility.

There is little information available on the digestibility of young horses, and few studies have compared the digestibility of 6-12 month old horses with mature horses. In one study, no significant difference was found in the apparent DM%, CP% or GE% digestibility of Coastal Bermuda hay between yearling and mature horses (Aiken *et al.*, 1989). This study concluded that the yearling horses had a similar ability to digest the constituents of the Coastal Bermuda hay as mature horses, and that mature horses could be used to evaluate the nutritional content of forages for growing horses (Aiken *et al.*, 1989). In a second study, no difference was found in the apparent digestibility of a mixed diet consisting of 67% lucerne cubes and 33% oat-based concentrate between six month old Thoroughbred weanling colts and mature Thoroughbred, Standardbred and Quarter Horse geldings. This study also suggested that at six months of age Thoroughbred horses have the same efficiency at utilising forage based concentrate diets as mature horses (Earing, 2011).

In the current study, the apparent DM and GE digestibility (70.55% and 68.51%, respectively) of the ensiled 60% lucerne and 35% cracked maize feed was very similar to the apparent DM and GE digestibility (70.30% and 65.90%, respectively) reported in weanling horses that were fed a diet of 60% lucerne hay and 40% concentrate (85% ground maize, 10% soybean meal and 5% minerals and additives) (Silva *et al.*, 2012). However, in the current study the apparent CP digestibility of the ensiled lucerne and cracked maize feed was lower (62.39%) than the level reported for the lucerne hay and concentrate diet (74.80%) by Silva *et al.* (2012). The apparent DM digestibility (69.5%) of a diet of 60% lucerne meal and 40% concentrate (80% ground maize and 20% soybean meal) fed to mature ponies (Hintz *et al.*, 1971) was also very similar to the current study. However, the apparent CP digestibility (75.5%) reported by Hintz *et al.* (1971) was very similar to Silva *et al.* (2012) and therefore also higher than the current study.

A possible explanation for the low apparent digestibility of CP in the current study compared to other studies, may be due to the physical method of crushing that was used to process the maize. The process of cracking maize has been shown to result in a lower enhancement of the availability of maize starch in the foregut and consequently lower pre-caecal digestibility (Jose-Cunilleras *et al.*, 2004; Vervuert *et al.*, 2004; Julliand *et al.*, 2006), when compared to grinding which increases the pre-caecal digestibility of starch (Julliand *et al.*, 2006). In addition, the concentrate rations that were fed in the Silva *et al.* (2012) and Hintz *et al.* (1971) studies consisted of 10-20% soybean meal of which approximately 75% of CP is digested pre-caecally (Farley *et al.*, 1995).

Ponies are commonly used in nutritional studies instead of horses to reduce costs, and because they are able to tolerate the confined conditions of digestibility studies better than horses (Hintz, 1990). While there is a trend for ponies to have slightly more efficient nutrient digestibility than horses (Slade and Hintz, 1969; Vermorel *et al.*, 1997), several studies have found no significant difference in apparent digestibility between horses and ponies (Hintz, 1990), when comparing mature Thoroughbreds and Shetland ponies (Slade and Hintz, 1969), and mature Standardbred horses and ponies (breed unspecified) (Vermorel *et al.*, 1997). In addition, no difference was found in the apparent digestibility of a mixed diet consisting of 85% meadow hay and 15% concentrate (50% ground barley, 45% soybean meal and 5% molasses and minerals) between heavy breed mares (Comtosis and Breton) and half breed (Comtosis cross and Breton cross) light geldings (Martin-Rosset *et al.*, 1990). While these studies justify the practice of using ponies in nutritional studies to evaluate the foodstuffs for horses (Slade and Hintz, 1969; Hintz, 1990), one study reported Shetland ponies (1-2 years old) having a significantly lower apparent digestibility of organic matter and GE than mature Thoroughbred horses and Highland ponies (Cuddeford *et al.*, 1995).

To the author's knowledge, the only apparent digestibility studies of ensiled forages by equines have been undertaken with mature ponies (Moore-Colyer and Longland, 2000; Hale and Moore-Colyer, 2001; Bergero *et al.*, 2002; Bergero and Peiretti, 2011). When the apparent digestibility of an ensiled and cracked maize feed was compared to the apparent digestibility of another ensiled legume forage (red clover silage), the DM and CP apparent digestibility of the silage by ponies (74% and 80%, respectfully) was much higher (Hale and Moore-Colyer, 2001). This may in part be due to single forage diets having higher apparent digestibilities than mixed feeds (Cuddeford *et al.*, 1995).

The apparent DM digestibility of the ensiled lucerne and cracked maize feed in the current study (71%) was higher than measurements reported for ensiled grass forages

(54-67%) in ponies (Moore-Colyer and Longland, 2000; Hale and Moore-Colyer, 2001; Bergero *et al.*, 2002; Bergero and Peiretti, 2011). The higher apparent DM digestibility of the feed in the current study is consistent with other studies that have shown lucerne hay to have a significantly higher apparent DM digestibility than grass hays (Crozier *et al.*, 1997; LaCasha *et al.*, 1999).

The apparent CP digestibility of the ensiled lucerne and cracked maize feed in the current study (62.40%), was however within the range reported for ensiled grass forages (48-76%) in ponies (Moore-Colyer and Longland, 2000; Hale and Moore-Colyer, 2001; Bergero *et al.*, 2002; Bergero and Peiretti, 2011). The lower apparent CP digestibility of the ensiled lucerne and cracked maize feed is not consistent with other studies where lucerne hays have been reported as having a higher apparent CP digestibility than grass hays (Crozier *et al.*, 1997; LaCasha *et al.*, 1999).

The apparent DM digestibility of lucerne hay was lower in yearling Quarter Horses (63%) (LaCasha *et al.*, 1999) and 2-6 year old Arabian horses (58%) (Crozier *et al.*, 1997) than the feed in the current study which was expected, as the ensiling process normally increases the digestibility of forages (Lewis, 2005). However, the apparent CP digestibility reported for lucerne hay was 73% (Crozier *et al.*, 1997) and 83% (LaCasha *et al.*, 1999) which were both higher than the feed in the current study (71%).

The ensiled lucerne and cracked maize feed used in the current study had a higher apparent DM digestibility than that reported for grass hays (43-60%) in horses (Aiken *et al.*, 1989; Crozier *et al.*, 1997; LaCasha *et al.*, 1999; Ordakowski-Burk *et al.*, 2006; Staniar *et al.*, 2010). However, the apparent CP digestibility of the feed in the current study by Thoroughbred weanling horses was within the range reported for grass hays by horses (43-69%) (Aiken *et al.*, 1989; Crozier *et al.*, 1997; LaCasha *et al.*, 1999; Ordakowski-Burk *et al.*, 2006; Staniar *et al.*, 2010), which may be due to the low pre-caecal digestibility of the cracked maize.

The method of total faecal collection to estimate apparent digestibility requires substantial time and labour investment (Sutton *et al.*, 1977). It is therefore important to determine the minimum duration of total faecal collection that is required to achieve consistent apparent digestibility measures of DM, CP and GE. In one study no significant difference was found in the apparent digestibility of nitrogen and energy by horses when the number of sampling days was reduced from seven to four days (Sutton *et al.*, 1977).

In the current study the variability of apparent digestibility measures of DM%, CP% and GE% decreased with the duration of faecal collection, and as the number of separate 12 hour faecal samples pooled per horse increased.

However, there was no significant difference between the duration of time the faecal samples were taken over, and the measurements of apparent DM CP, and GE digestibility of the ensiled lucerne and cracked maize feed. The relatively low variability that is evident in the data in the current study throughout the period of sample collection among the weanling horses may be influenced by the weanling fillies being sired by the same stallion and having experienced the same management and feeding practices and diet since birth.

3.6 CONCLUSION

The weanling horses in the current study had a lower VFI of the ensiled lucerne and cracked maize feed than the majority of other studies where weanlings and yearlings were fed lucerne hay or mixed lucerne hay and concentrate feed. The apparent DM and GE digestibilities of the feed were similar to that reported in weanling horses fed grass or lucerne hay alone, or in combination with concentrate rations. The lower apparent CP digestibility of the feed in the current study may be related to the low pre-caecal digestibility of the cracked maize. The variability of apparent digestibility measures of DM%, CP% and GE% decreased with duration of faecal collection. While the apparent digestibility measurements from 12 hours of collection are not significantly different to 96 hours of collection, the 12 hour apparent digestibility measurements are slightly lower, and the standard error of the measurements decreased as the duration of faecal collection increased. In summary, this study suggests that 12 hours of total faecal collection is adequate to measure DM, CP and GE apparent digestibility.

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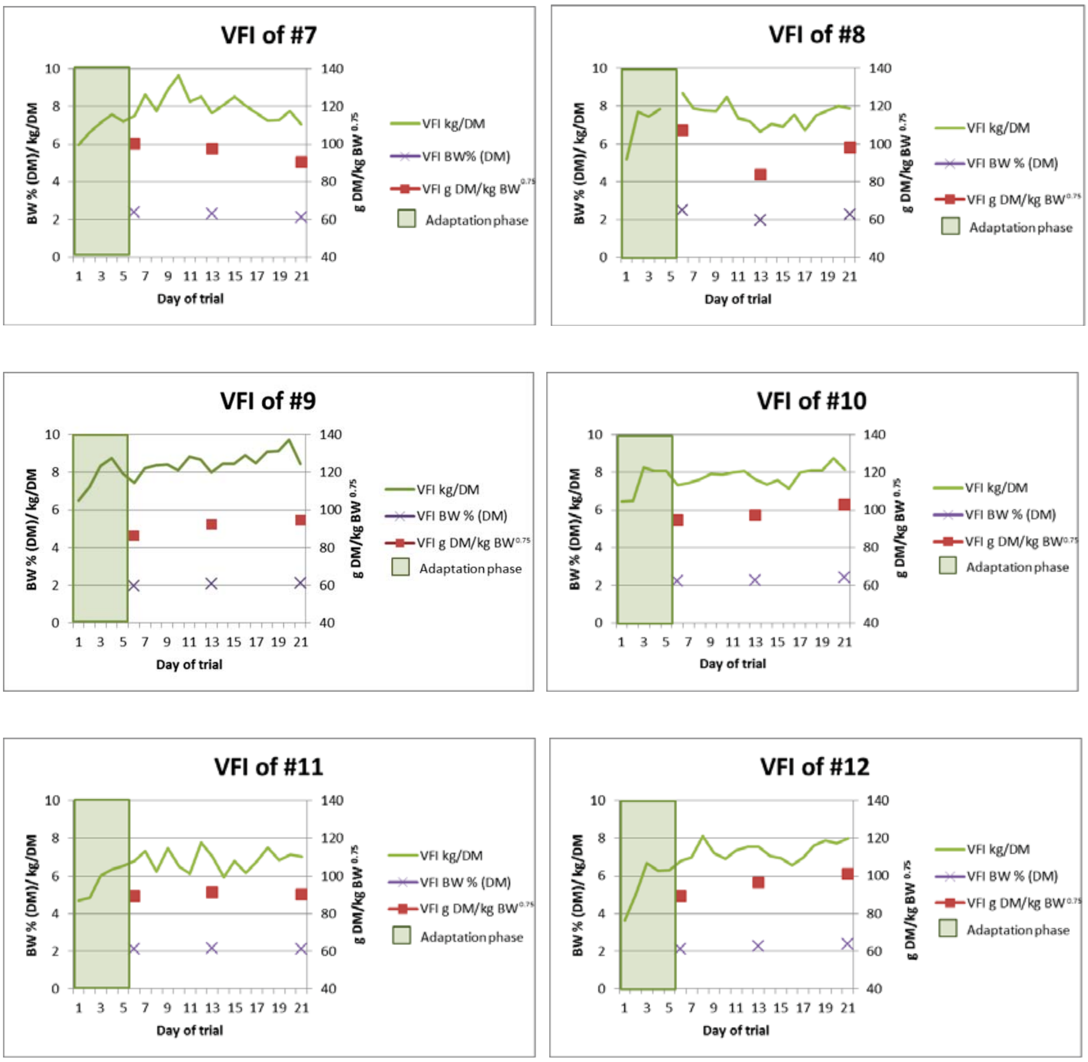
3.8 APPENDICES B



Appendix B1 The voluntary feed intake of individual Thoroughbred weanlings on a DM basis as kg/DM per day from day 1-21, and g DM/kg BW$^{0.75}$ and BW % on days 6, 13 and 21 during the VFI and digestibility study. The period of adaptation is shown as a shaded area on the graphs. No VFI data was collected from weanling #8 on day 5 of the study.

Appendix B2 The intakes, faecal outputs, amounts apparently absorbed and digestibility of DM, crude protein and energy of an ensiled lucerne and cracked maize supplementary feed fed to Thoroughbred weanling horses.

Dry Matter

Weanling ID	7	8	9	10	11	12
12 hour Collection						
Intake (kg/day)	3.76	4.44	4.12	3.84	4.69	4.11
Faecal output (kg/day)	1.16	0.97	1.30	1.01	1.15	1.19
Apparent absorption (kg/day)	2.60	3.47	2.82	2.83	3.54	2.92
Digestibility %	66.07	72.18	67.93	72.94	72.99	68.21
24 hour Collection						
Intake (kg/day)	3.46	4.66	3.99	3.65	2.81	3.52
Faecal output (kg/day)	1.02	0.90	1.16	1.00	0.99	1.15
Apparent absorption (kg/day)	2.44	3.76	2.83	2.65	1.82	2.37
Digestibility %	69.04	73.58	72.00	72.78	70.88	66.93
48 hour Collection						
Intake (kg/day)	3.71	4.77	4.23	4.01	3.43	4.00
Faecal output (kg/day)	1.01	1.01	1.22	0.98	0.92	1.15
Apparent absorption (kg/day)	2.70	3.76	3.01	3.03	2.51	2.85
Digestibility %	69.52	71.06	70.53	73.38	71.65	67.44
72 hour Collection						
Intake (kg/day)	3.44	4.48	4.23	3.91	3.00	3.46
Faecal output (kg/day)	1.02	0.97	1.23	0.98	0.99	1.14
Apparent absorption (kg/day)	2.42	3.51	3.00	2.93	2.01	2.32
Digestibility %	69.79	72.37	70.90	74.01	69.46	67.66
96 hour Collection						
Intake (kg/day)	3.94	4.40	3.98	3.98	2.93	3.82
Faecal output (kg/day)	0.99	1.01	1.19	1.01	0.99	1.15
Apparent absorption (kg/day)	2.95	3.39	2.79	2.97	1.94	2.67
Digestibility %	70.23	71.51	71.18	73.31	69.41	67.71

Crude Protein

Weanling ID	7	8	9	10	11	12
12 hour Collection						
Intake (kg/day)	0.45	0.46	0.53	0.50	0.56	0.49
Faecal output (kg/day)	0.21	0.17	0.20	0.17	0.19	0.20
Apparent absorption (kg/day)	0.24	0.29	0.33	0.33	0.37	0.29
Digestibility %	74.89	79.19	72.33	78.23	77.85	75.47
24 hour Collection						
Intake (kg/day)	0.41	0.44	0.56	0.48	0.34	0.42
Faecal output (kg/day)	0.18	0.16	0.19	0.17	0.15	0.19
Apparent absorption (kg/day)	0.23	0.28	0.37	0.31	0.19	0.23
Digestibility %	76.87	80.03	77.27	78.61	75.30	73.56
48 hour Collection						
Intake (kg/day)	0.44	0.48	0.57	0.51	0.41	0.48
Faecal output (kg/day)	0.17	0.18	0.20	0.16	0.15	0.20
Apparent absorption (kg/day)	0.27	0.30	0.37	0.35	0.26	0.28
Digestibility %	76.30	78.63	76.01	79.01	77.12	74.79
72 hour Collection						
Intake (kg/day)	0.41	0.47	0.54	0.51	0.36	0.42
Faecal output (kg/day)	0.17	0.17	0.20	0.16	0.17	0.20
Apparent absorption (kg/day)	0.24	0.30	0.34	0.35	0.19	0.22
Digestibility %	76.69	79.04	76.34	79.43	76.74	75.11
96 hour Collection						
Intake (kg/day)	0.47	0.48	0.53	0.48	0.35	0.46
Faecal output (kg/day)	0.17	0.17	0.20	0.17	0.17	0.19
Apparent absorption (kg/day)	0.30	0.31	0.33	0.31	0.18	0.27
Digestibility %	77.51	78.13	77.03	79.23	76.49	74.25

Energy

Weanling identification	7	8	9	10	11	12
12 hour Collection						
Intake (MJ/day)	42.71	43.53	50.40	46.76	53.21	46.62
Faecal output (MJ/day)	16.01	13.62	17.40	14.28	16.16	16.85
Apparent absorption (MJ/day)	26.70	29.91	33.00	32.48	37.05	29.77
Digestibility %	69.30	75.27	70.20	76.02	75.99	72.04
24 hour Collection						
Intake (MJ/day)	39.26	41.42	52.83	45.25	31.83	39.91
Faecal output (MJ/day)	10.10	12.27	15.07	13.51	13.05	15.05
Apparent absorption (MJ/day)	29.16	29.15	37.76	31.74	18.78	24.86
Digestibility %	75.53	75.83	73.14	74.78	72.35	68.55
48 hour Collection						
Intake (MJ/day)	42.09	45.43	54.14	48.02	38.92	45.40
Faecal output (MJ/day)	10.41	13.44	16.09	12.85	12.24	14.90
Apparent absorption (MJ/day)	31.68	31.99	38.05	35.17	26.68	30.50
Digestibility %	71.81	73.01	72.12	74.64	73.28	68.69
72 hour Collection						
Intake (MJ/day)	39.06	44.40	50.87	47.95	34.06	39.23
Faecal output (MJ/day)	14.68	12.94	16.05	13.12	13.12	14.62
Apparent absorption (MJ/day)	24.38	31.46	34.82	34.83	20.94	24.61
Digestibility %	71.99	74.04	72.12	75.68	71.17	68.56
96 hour Collection						
Intake (MJ/day)	44.70	45.14	49.87	45.11	33.21	43.37
Faecal output (MJ/day)	11.98	13.20	15.65	13.33	13.00	14.58
Apparent absorption (MJ/day)	32.72	31.94	34.22	31.78	20.21	28.79
Digestibility %	71.49	72.97	72.60	74.89	70.92	68.33

CHAPTER 4 GENERAL DISCUSSION

The primary aim of this thesis was to examine if Thoroughbred weanling horses on pasture and supplemented with a fibre-based feed could achieve a similar growth pattern to Thoroughbred weanling horses supplemented with a commercial concentrate weanling feed when managed under commercial stud farm conditions.

This thesis demonstrates that Thoroughbred weanlings supplemented with a fibre-based feed can achieve similar growth patterns to weanlings fed a concentrate-based supplement. However, results do suggest that the palatability of the fibre-based feed was lower than the concentrate-based feed as the fibre-fed weanlings continuously left the feed to graze pasture and did not always consume the supplementary feed within 24 hours.

The management practices New Zealand Thoroughbred stud farms have been studied in detail (Rogers *et al.,* 2007; Stowers *et al*., 2009; Hirst, 2011), however, there is very little knowledge of the growth patterns of New Zealand Thoroughbred foals that are raised commercially for sale as yearlings, and of the effect nutrition can have on these growth patterns.

The fibre-based feed appears to be a feasible alternative supplementary feed to concentrate-based feeds for Thoroughbred weanlings. In fact, the longer duration that the weanlings spent consuming the fibre-based diet coupled with frequent grazing interruptions may be beneficial in promoting more natural feeding behaviours in weanling horses and may encourage more efficient utilisation of available pasture.

During the VFI work, the daily DE intake from the fibre-based feed by the weanlings was above the NRC (2007) DE requirements for their age and body weight, indicating that a fibre-based feed is capable of meeting the DE requirements of the weanlings, and that the weanlings are capable of consuming this volume of feed when it is fed *ad libitum.* This is also reflected in the mean ADG of 0.78 kg/day they achieved during the VFI and digestibility study.

By managing the weanling horses on a commercial Thoroughbred stud farm they were faced with commercial constraints which limited the control of some aspects of the study, and resulted in the weanlings being frequently moved from paddock to paddock with differing amounts and quality of pasture available in each paddock. Horses on commercial stud farms are also often at risk of illness (*Streptococcus equi var. equi* infection in this case), due to the frequent arrival and departure of new horses. The weanlings that were affected by strangles were able to recover and achieve similar growth rates to the healthy weanlings in their group at the end of the study.

The ensiled lucerne and cracked maize feed (fibre-based feed) is a relatively new feed product and little is known about it, including any seasonal variation, the variability between feed bags and batches or during processing of the feed product. Two feed samples were analysed during the apparent digestibility study and further work is required to better understand the variability in the product.

Future applications and further work

In order to have a better understanding of the ensiled lucerne and cracked maize feed, further VFI and apparent digestibility studies are needed to compare the VFI and apparent digestibility of the ensiled feed with the same feed pre- ensiled, as well as comparing the VFI and apparent digestibility of the ensiled feed in young and adult horses. The low apparent CP digestibility of the ensiled lucerne and cracked maize feed also warrants further investigation, and ways of increasing the apparent CP digestibility needs to be explored.

Further, more sensitive studies to determine if there are any significant differences in apparent digestibility measurements in faecal samples collected hourly versus 12 hourly could further increase the accuracy of total faecal collection during apparent digestibility.

Several studies have evaluated the behaviour of foals' fed high sugar and starch or high fat and fibre rations during weaning. To further examine the suitability of the ensiled lucerne and cracked maize feed for weanling horses it would be ideal to study the behaviour of foals fed either this fibre-based feed or a concentrate-based weanling feed prior to, during and directly after weaning. It would also be of interest to conduct a controlled palatability test of the ensiled lucerne and cracked maize feed as the palatability of this feed was questionable during the growth study.

The results of this study will further the current knowledge on growing Thoroughbred horses within the New Zealand racing industry, and may encourage stud farms to supplement foals with fibre-based feeds.

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