Some Factors affecting the Digestible Energy Requirements and Dry Matter Intake of Mature Donkeys and a Comparison with Normal Husbandry Practices

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DECLARATION

This thesis is my own composition. The work contained within this thesis has been completed by myself and has not been submitted previously for any other degree.

Signed:______________________

ABSTRACT

The purpose of this study was to compile practical feeding guidelines for donkeys in the UK. Current guidelines are to feed 0.75 of horse feeding recommendations on a body weight basis. However, the superior digestive efficiency of donkeys, compared to horses, may render the use of horse recommendations inappropriate. The formulation of guidelines specific to donkeys would enable owners to calculate their donkey's requirements with greater accuracy and prevent overfeeding.

A postal survey, used to gain information on the body condition score of donkeys in the UK, and the husbandry and feeding practices used to manage them, indicated that approximately 24% of donkeys in the UK are overweight. Feeding practices indicated that although owners were aware of their donkey's requirement for fibrous forages, the practice of feeding unnecessary concentrates, chaffs and high energy forages, in addition to grazing, was the likely cause of donkeys becoming overweight. The finding that the majority (85 – 90%) of donkeys were kept as non-working companion animals also reduced the need for owners to feed higher energy foods to their donkeys. Results also suggested that owners were unsure of how to adjust their donkey's diet to account for seasonal changes in requirements and pasture availability, as most owners' adjusted grazing access, and not the feeding of supplementary feeds.

From a study of dry matter (DM) and digestible energy (DE) intakes by 20 mature donkeys maintaining weight during each UK season, the maintenance DE requirements of donkeys were calculated. Results showed no effect of sex on DM or DE intake. Season significantly ($P<0.001$) affected DM and DE intakes, implying increased requirements in winter compared to spring, summer and autumn. Dry

matter intakes (DMI) increased from 51g/kg $BW^{0.75}$ in spring, summer and autumn to 66g/kg $BW^{0.75}$ in winter. Digestible energy requirements increased from 0.32MJ/kg $BW^{0.75}$ in spring, summer and autumn to 0.43MJ/kg $BW^{0.75}$ in winter. Comparison of results with horse recommendations showed considerably reduced requirements by donkeys. Horse recommendations overestimated DE requirements in summer and winter by 82 and 30%, respectively, making horse recommendations unsuitable for calculating donkey energy requirements.

Husbandry practices commonly used by owners to manage their donkeys grazing access (grazing time, grazing area, strip grazing), were assessed for their effect on DMI by grazing donkeys in summer and autumn, using *n*-alkanes. The effect of grazing time was assessed by restricting donkeys to 8, 12 or 23 hours grazing per day. Season significantly affected food intake with donkeys in the 8 and 23 hour grazing groups eating more during summer when pasture availability was greater. Donkeys responded to the poorer quality summer pasture by grazing more intensively but less selectively, increasing the rate at which food was consumed. Grazing time was only influential over grass intake in summer, when pasture was more abundant. Restricting donkeys to 12 hours or less grazing per day significantly ($P<0.001$) reduced their grass intake compared to that of donkeys with 23 hours access. When grazing sparse pastures (autumn), grazing time did not influence grass intake, indicating an effect of herbage mass on grazing behaviour. Herbage mass was the most influential factor over diet composition (percentage of grass and straw consumed) in a second grazing study assessing the affect of strip grazing and set stocking systems on intake by grazing donkeys during summer and autumn. Herbage mass per donkey was higher in the set stocking system during both seasons, resulting

in higher grass intakes. Determining if either grazing system was more effective at regulating grass intake was prevented due to differences in pasture availability between study sites.

It is concluded that donkeys have lower DMI and maintenance DE requirements than horses, requiring donkey feeding guidelines to be formulated. Excess body weight in donkeys is caused in part, by the feeding of energy dense feeds in addition to low energy forages. Most owners place little nutritional importance on pasture, despite its potential to provide a large percentage of daily DM, DE and nutrient intake. Therefore nutritional guidelines must include advice on how to manage access to grazing, and how to feed donkeys with access to pasture. Restricting grazing time to 8 hours a day did reduce grass intake by donkeys, but was only effective when grazing abundant pastures. Providing *ad libitum* straw to grazing donkeys allows them to satisfy their DM and dietary fibre requirements without consuming excess energy.

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ABBREVIATIONS

ADF	Acid-detergent fibre
ADL	Acid-detergent lignin
AIA	Acid-insoluble ash
ANOVA	Analysis of variance
BW	Body weight
$BW^{0.75}$	Metabolic body weight
CC	Cytoplasmic carbohydrates
CF	Crude fibre
CH_4	Methane
CO_2	Carbon dioxide
CP	Crude Protein
Cr_2O_3	Chromium sesquioxide
CTVM	Centre for Tropical Veterinary Medicine
C_{25}	Pentacosane
C_{29}	Nonacosane
C_{31}	Monatriacontane
C_{32}	Dotriacontane
C_{33}	Tritriacontane
DCP	Digestible crude protein
DE	Digestible energy
DEI	Digestible energy intake(s)
DM	Dry matter
DMD	Dry matter digestibility
DMI	Dry matter intake(s)
GE	Gross energy
GIT	Gastrointestinal tract
ha	Hectare(s)
Hrs	Hours
kcal	kilocalorie
kJ	kilojoule
M	Maintenance
M	Meters
MAFF	Ministry of Agriculture, Fisheries and Food
MJ	Megajoule
MRT	Mean retention time
MW	Weetabix Minis
N	Nitrogen
NCGD	Neutral cellulase plus gamanase
NDF	Neutral-detergent fibre
Ne	Endogenous nitrogen
NE	Net energy
NED	National Equine Database
NRC	National Research Council
OM	Organic matter
O_2	Oxygen

rDM	Residual dry matter
RQ	Respiratory quotient
TNZ	Thermoneutral Zone
U	Urine
UFC	Horse feed unit
UK	United Kingdom
vDMI	Voluntary dry matter intake
VFA	Voluntary fatty acid

“*To carry his load without resting, not to be bothered by heat or cold and always be content; these three things we can learn from a donkey*”

Indian proverb

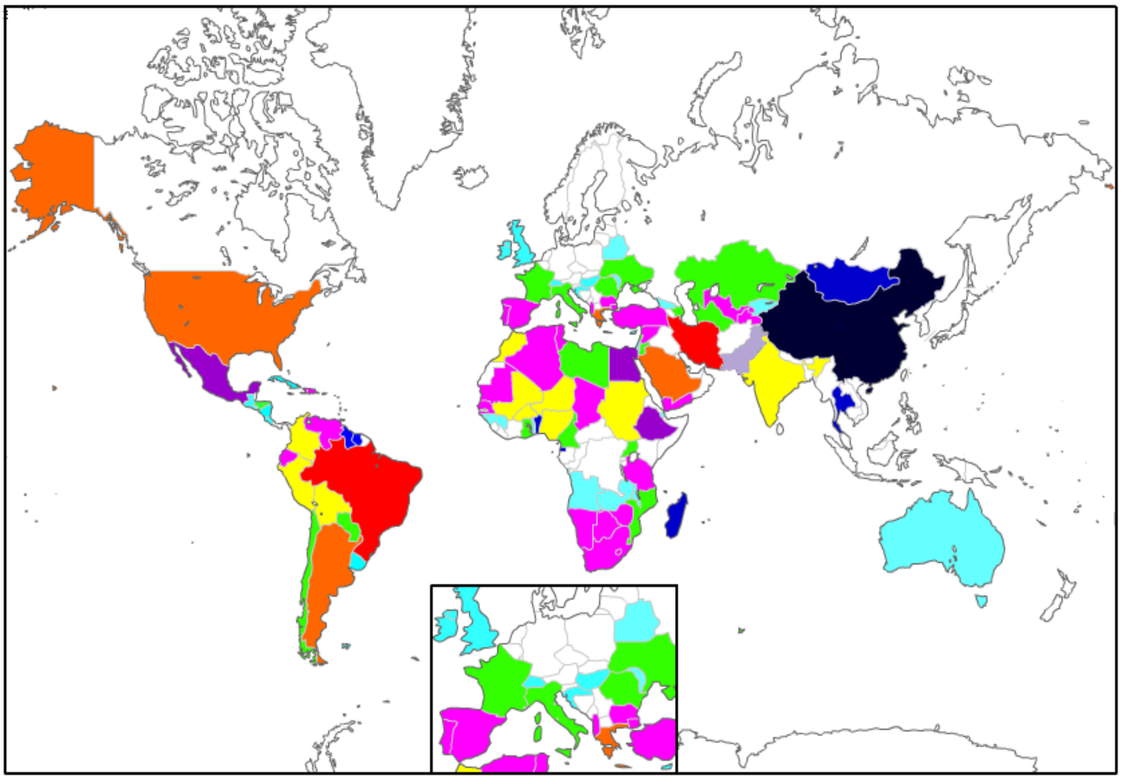
CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

The world donkey population in 2003 was estimated at just over 40 million (FAOSTAT, 2004). Ninety seven percent (~39 million) of the donkey population live in developing countries (Figure 1.1.) where they are used extensively by poorer communities. Most frequently used as pack animals to carry food, water and transport goods, donkeys ease the labour burden and improve the quality of their owners' lives (Pearson, Nengomasha & Krecek, 1999; Pearson *et al*., 2001; Wold, Tegegne & Yami, 2004). As a result, donkeys are of economic importance to the people living in poorer communities. However, the low social status of donkeys has resulted in their management and welfare needs being largely neglected (Fernando & Starkey, 2004). The needs of the donkey come low in the priority list of poorer people who usually prefer to direct resources to food producing livestock (De Aluja, 1998). The high workload of many donkeys increases their demand for energy whilst reducing the time available to eat. As a result working donkeys in developing countries commonly have poor body condition and consequently have lower resistance to disease and are at increased risk of injury.

In contrast, donkeys in the United Kingdom (UK) are of little economic value, being primarily kept as pets or companions for leisure horses, and research into the welfare and management of these donkeys has been minimal. The keeping of donkeys with horses has likely promoted the view that donkeys should be managed as small horses. However, from a small number of studies into donkey nutrition it is evident that donkeys have superior digestive ability compared to horses and therefore should be at least fed differently.

Figure 1.1. Estimated global population and distribution of donkeys in 2003 (FAOSTAT, 2004).



Population

- 8,000,000 - 9,000,000
- 4,000,000 - 5,000,000
- 3,000,000 - 4,000,000
- 1,000,000 - 2,000,000
- 500,000 - 1,000,000
- 100,000 - 500,000
- 50,000 - 100,000
- 10,000 - 50,000
- 1,000 - 10,000
- <1000

o 0 or insufficient data to estimate population

Donkeys digest foods more efficiently than horses and ponies (Tisserand, Faurie & Toure, 1990; Pearson & Merritt, 1991; Pearson, Archibald & Muirhead, 2001) but less efficiently than sheep and cattle (Butterworth, Mosi & Nuwanyakpa, 1987; Julliand *et al*., 1997) (Table 1.1). Comparisons of voluntary food intake between donkeys and ponies have revealed lower dry matter intakes (DMI) by donkeys relative to their metabolic body size (Tisserand *et al*., 1990; Pearson & Merritt, 1991; Pearson *et al*., 2001). More efficient digestion by donkeys compared to horses and ponies, has been attributed to longer retention times of digesta within the gastrointestinal tract (GIT), extending the time digesta is exposed to digestive and fermentative processes, increasing the proportion of food utilised by the donkey (Tisserand *et al*., 1990; Pearson & Merritt, 1991; Cuddeford *et al*., 1995; Pearson *et al*., 2001).

Table 1.1. Comparison of apparent dry matter digestibility (DMD) by donkeys, ponies and ruminants fed forage diets.

Diet	**Donkey (*n*)**	**Pony (*n*)**	**Ruminant (*n*)**	**Reference**
	DMD (%)			
Good quality hay	63 (3)	58 (3)	-	Tisserand *et al*. (1990)
Poor quality hay	53 (3)	51 (3)	-	
Molassed wheat straw	50 (2)	43 (2)	-	
Alfalfa hay	63 (4)	58 (4)	-	Pearson *et al*. (2001)
Oat straw	50 (4)	43 (4)	-	
Meadow hay	51 (6)	-	61 (6)	Butterworth *et al*. (1987)
Oat straw	49 (6)	-	52 (6)	
	NDF Digestibility (%) *			
Lucerne-orchard grass hay	46 (3)	41 (3)	55 (3)	Julliand *et al*. (1997)
Wheat straw	26 (3)	24 (3)	43 (3)	

NDF: Neutral-detergent fibre
n: number of animals
* Measured *in situ* using the mobile bag technique over 48 hours

A more recent study by Carretero-Roque *et al*. (2005) also suggests that donkeys have lower digestible energy (DE) requirements than horses. Daily digestible energy intakes (DEI) required by donkeys in Toluca, a temperate region of Mexico, to maintain body weight, averaged 62% of DEI recommended for maintenance in current feeding guidelines (NRC, 2007) for ponies of equivalent weight. A lower DE requirement and greater digestive efficiency potentially reduces the amount of food required by donkeys.

In the UK, pasture quality and quantity is generally high compared to that to which donkeys are adapted by evolution (Minson, 1990). Ample food resources combined with a sedentary lifestyle increase the risk of obesity in donkeys. Anecdotal evidence from donkeys kept in sanctuaries around the UK indicates obesity is a problem in the animals they care for (Personal Communication; Faith Burden, The Donkey Sanctuary, UK). Hyperlipaemia (Reid & Mohammed, 1996), laminitis (Reilly, 2000) and Equine Metabolic Syndrome (Johnson, 2002), problems associated with overfeeding, have been reported in donkeys. The problem of excess body weight has recently been measured in horses in the UK and America. Forty-five percent of the 319 leisure horses assessed in Scotland (Wyse *et al*., 2008) and 51% of the 300 horses assessed in Virginia, USA (Thatcher *et al*., 2008) were overweight or obese. The prevalence of obesity in horses was similar to that most recently reported for dogs in the UK (52% of 399 dogs) (Holmes *et al*., 2007), suggesting that the risk of becoming obese is similar in horses to that in companion animals. Earlier studies assessing body condition in cats and dogs reported obesity rates of 19 – 35% in cats (Donoghue & Scarlett, 1998; Robertson, 1999; Allan *et al*., 2000; Lund *et al*., 2005) and 23 – 41% in dogs (Edney & Smith, 1986; Donoghue *et* *al*., 1991; Robertson, 2003; McGreevy *et al*., 2005; Lund *et al*., 2006). The higher rate of obesity in the study by Holmes *et al*. (2007) suggests an increase in recent years in the prevalence of obesity among companion animals. Reasons for an increasing rate of obesity in the animals we care for have not been investigated, although certain companion animal management practices that increase their risk of obesity have been identified. The keeping of donkeys as companion animals may make them susceptible to the same risks.

Feeding a high calorific diet (Lund *et al*., 2005, 2006) and neutering (Edney & Smith, 1986; Lund *et al*., 2005, 2006; McGreevy *et al*., 2005; German, 2006; Holmes *et al*., 2007) increased the likelihood of cats and dogs gaining weight. The type of food offered was not associated with increased body weight in cats and dogs (Edney & Smith, 1986; German, 2006) but the feeding of table scraps, treats and snacks was more common in overweight and obese animals than in healthy or underweight animals (Kienzle, Bergler & Mandernach, 1998; German, 2006; Kienzle & Bergler, 2006). The feeding of more treats and snacks to overweight cats and dogs was identified by Kienzle *et al*. (1998) and Kienzle & Bergler (2006) as a way of owners showing their animals affection, compared to owners of healthy weight animals where additional owner-animal interaction (game playing, extra exercise) was more frequently used. It appears that owners contribute to their animals weight gain by both increasing their calorific intake and minimising their activity level. A further contributing factor to the problem of obesity in dogs (Holmes *et al*., 2007) that has also been identified for horses (Wyse *et al*., 2008) was an inability or unwillingness by owners of overweight animals to recognise overweight and obese body conditions. Prevention of obesity in the animals we care for must therefore include education of owners in identifying a healthy animal in addition to the provision of feeding guidelines. The absence of feeding guidelines for donkeys prevents accurate calculation of their requirements and requires investigation.

1.2 STUDY AIMS

Maintenance of working and none working donkeys in healthy body condition requires owners to estimate feed requirements. However, the dearth of information on donkey feed requirements has prevented accurate dietary guidelines being compiled. Information on feeding practices, combined with an assessment of the body condition of donkeys in the UK, will provide an indication of the level of understanding owners have of their donkeys' nutritional requirements, and the suitability of different foods for donkeys. Identification of the husbandry practices people use to manage donkeys, particularly management of grazing access, will provide information to assist research into how husbandry methods influence food intake by donkeys. Together the information can be used to provide advice to owners on how to manage and feed their donkeys to help prevent obesity and associated health problems.

1.2.1 Scope of the Thesis

The following research was undertaken with the aim of compiling feeding guidelines for donkeys in the UK. Firstly, the findings of a survey to investigate the prevalence of obesity in UK donkeys and the normal husbandry practices of keeping donkeys in the UK are reported. Secondly, the results of three experiments to evaluate feed requirements are reported. The first experiment determined the effect of season and sex on maintenance DE requirements and the second and third experiments measured the effect of management practises on donkey DMI in different seasons. These practises included the effect of restricted grazing time (experiment 2) and the effect of set stocking and strip grazing (experiment 3). Those factors affecting the DE and DMI requirements of donkeys are discussed in the review of literature and are compared with the experimental results obtained in the current study in the general discussion.

CHAPTER 2
REVIEW OF LITERATURE

2.1 INTRODUCTION

The formulation of feeding guidelines for donkeys should begin with calculation of voluntary food intake and maintenance energy requirements. Results gained in the experimental situation must then be applied to management methods used to care for donkeys. To enable this application it is essential to understand the external factors affecting the donkey's food intake and energy requirements. It is also essential to understand physiological mechanisms that affect the donkey's energy requirements and digestive efficiency. Evolving in a desert environment, where food resources are sparse and where it is necessary to travel over large areas to gain adequate food intake, the donkey has developed physiological adaptations and feeding strategies to cope with such challenges. For ease of discussion these internal and external factors are divided into three categories 1) plant factors, 2) environmental factors and 3) animal factors. Although discussed separately, these factors interact in their affect on intake and energy requirements. How they affect free roaming, grazing animals compared to how they affect housed animals will also be discussed, as these influences are important when deciding management and feeding practices.

2.2 DRY MATTER INTAKE

2.2.1 Plant Factors

Plant characteristics are highly influential over nutritive value and food intake. Defence mechanisms developed by plants affect the strategies herbivorous animals use to gather, process, and utilise plant material and their success in satisfying nutrient demand. The composition and structure of plants are two of the primary determinants of plant nutritive value (Van Soest, 1982).

Nutritional Components

Plants are comprised of soluble cell contents and soluble and insoluble cell wall components. Insoluble components (cellulose, hemicelluloses and lignin) provide rigidity and enable plants to have structure, however, the ability of herbivores to utilise such components is limited by the degree of microbial fermentation occurring in the GIT. In turn the success of fermentation is affected by the composition and amount of cell wall material. As plants mature the proportion of cell wall within the plants' cells increases due to the development of a secondary cell wall (Jung & Allen, 1995; Bach Knudsen, 2001). Coinciding with this development is the deposition of lignin, an indigestible polymer, into the primary and eventually secondary cell walls (Jung & Allen, 1995). The overall increase in the amount of cell wall material makes mature plants less nutritious compared to younger plants, requiring greater quantities of mature plants to be consumed to meet nutritional demand. However, cell wall content (NDF fraction when analysed in the laboratory) has been negatively correlated with intake in ruminants (Van Soest, 1965; Mertens, 1994) due to the effect of rumen fill. Cell wall components take longer to breakdown to particles small enough ($\leq$2mm) to pass through the reticulo-omasal orifice (Campling, Freer & Balch, 1961; Freer & Campling, 1963; Van Soest, 1973). This increased retention time prolongs the effect of rumen fill, reducing food intake (Thornton & Minson, 1972).

The relationship between cell wall content and intake in equids is less defined than for ruminants. Studies by Uden and Van Soest (1982a,b) showed cell wall content had little effect on intake in horses and ponies compared to that in large and small ruminants. Horses and ponies (BW 132 – 388kg) consumed more DM and cell wall (g/kg $BW^{0.75}$) compared to heifers (243 – 555kg) (Uden & Van Soest, 1982b). The authors attributed the higher intakes to the absence of a physical obstruction, equivalent to the reticulo-omasal orifice, in the equine GIT, reducing retention time in the equine foregut leading to a faster rate of passage. Correlations between forage NDF content and intake reported for equids support the findings of Uden and Van Soest (1982a,b), indicating that food intake by equids is less affected by cell wall content. Cymbaluk (1990a), feeding mature horses different hay types, reported a correlation of only 0.27 for NDF content and voluntary DMI (vDMI) (g/kg $BW^{0.75}$) compared to 0.63 for cattle fed the same diets. Similarly weak correlations (r^2 0.11 – 0.13) were reported by Dulphy *et al*. (1997a) for horses fed grass hays, alfalfa hays and straws.

Forages of higher NDF content are consumed at lower intakes by equids than less fibrous forages and concentrate feeds (Pearson & Merritt, 1991; Mueller *et al*., 1994; Dulphy *et al*., 1997b; Pearson *et al*., 2001), which is thought to be an effect of increased handling and processing time (Table 2.1). The negative effect of plant cell wall on handling and chewing times in equids is thought to be due to plants of high cell wall content being more resistant to fracture than those of low cell wall content (Wright & Illius, 1995), requiring longer chewing times to reduce particle size prior to swallowing. Equids increase the number of chews per kg DM when consuming fibrous forages compared to when eating an equivalent amount of cereal grains or less fibrous forages. As chewing time increases with increasing NDF content, DMI rate decreases (Smith, 1999).

Table 2.1. Effect of neutral-detergent fibre (NDF) content on chewing rates in horses and donkeys

Animal (BW)	Food	NDF (g/kg DM)	Chews (no./kg DM)	Chewing time (mins/kg DM)	Reference
Horse (500kg)	Hay	650 *	3400	40	Harris (1999)
	Oats	310 *	850	10	
Donkey (198kg)	Mixed hay (legume/orchardgrass)	646	6200	120	Mueller *et al.* (1998)
	Grass hay	658	6500	121	
Donkey (199kg)	Haylage	656	6000	116	Smith (1999)
(200kg)	Alfalfa hay (chopped)	382	3800	72	
(183kg)	Barley straw	824	8100	157	
Pony (210kg)	Haylage	656	7000	116	
(206kg)	Alfalfa hay (chopped)	382	3800	75	
(212kg)	Barley straw	824	9800	162	

* Taken from McDonald *et al.* (2002).

The fibrous portion of plants also affects nutrient digestibility and soluble nutrient content. Both of these factors influence intake through their effect on the quantity of nutrients gained per unit of food consumed. The acid-detergent fibre (ADF) fraction (cellulose and lignin content) of the cell wall correlates negatively with NDF digestibility (Van Soest, 1982) as lignin is the main limiting factor of forage digestibility (Jung & Deetz, 1993). Lignin is of no nutritional value to the animal and has an inhibitory effect on microbial fermentation of other cell wall components (Jung & Deetz, 1993). Cross linkages formed between lignin and hemicellulose resist enzymatic action and prevent degradation of hemicellulose, and due to its close association, cellulose (Moore & Jung, 2001). Digestibility of soluble cell contents is not affected by lignin although the level of soluble substances within the plant's cells is reduced as lignin content increases with plant maturity (Moore & Jung, 2001).

Species

Plants most frequently consumed by grazing herbivores are categorised as either legumes or grasses. Grasses are further divided into C3 (temperate) and C4 (tropical) species (Van Soest, 1982). Plant species differ in their structure, composition and nutritional content, with structure and composition affecting resistance to ingestion, mastication and digestion (Jung & Allen, 1995).

Plant stems provide rigidity and structure. As plants mature the amount of stem must increase to support increasing plant size and the need to flower and set seed, decreasing the plant's leaf:stem ratio. The stem provides support by increasing the proportion of cell wall and lignin in the stem's cells as the plant grows (Van Soest, 1982; Jung & Allen, 1995). The percentage of cell wall in stems of legume plants is generally less than in grass stems of equivalent maturity, with the stems of temperate grass species being less fibrous than those of tropical grasses (Wilson, 1993). The leaves of grasses are also more fibrous than those of legume plants due to the development of a lignified supporting midrib in grass leaves as the plant matures (Buxton & Redfearn, 1997). In contrast, the cell wall content of legume leaves remain relatively stable with increasing maturity (Nelson & Moser, 1995). However, the lignin content within the cell wall of legume leaves is generally higher than that of equivalently mature grass species (Moore & Hatfield, 1995). The lower cell wall content of legume leaves results in plants of higher soluble contents leading to higher DMI of legume forages compared to grass and straw forages by ruminants and equines (Warren *et al*., 1974; Crozier *et al*., 1997; Pearson *et al*., 2001). The lower cell wall content of C3 grasses also promotes higher intakes of these grass species compared to C4 grasses (Crozier *et al*., 1997; LaCasha *et al*., 1999). Differences in cell wall content between legume and grass species may also affect eating times through differences in fracture properties, influencing chewing times and thus DMI rates. However, the higher lignin content of legumes, compared to grasses, reduces cell wall digestibility, reducing the fermentable fibre fraction of legume plants (Moore & Hatfield, 1995).

Plant Architecture

The amount of pasture available to grazing animals is influenced by herbage mass (g/m^2) and herbage height (cm). However, how these factors affect pasture intake in equids has not received much attention. The effect of herbage mass on vDMI by grazing equids has only been investigated in one study. McMeniman (2003) found vDMIs by yearling horses grazing perennial grass pastures were not significantly affected by herbage mass. One reason for this lack of effect may have been lower herbage density of the pastures with greater herbage mass. Herbage density decreases as herbage height increases, with these two factors influencing bite dimensions, grazing behaviour and food intake in grazing ruminants (Griffiths & Gordon, 2003). Pasture height also influences bite depth, weight and rate in horses. Taller pastures allow for greater bite depth resulting in greater bite weight (g DM), but with a limiting effect on bite rate (g DM/min) (Naujeck & Hill, 2003; Edouard *et al*., 2009). Longer chewing times of larger bites and greater resistance of taller, more fibrous pastures to fracture, slow the bite rate (Laca, Ungar & Demment, 1994). Therefore the similar intakes of pastures with high ($356g/m^2$) and low ($40g/m^2$)

herbage mass reported by McMeniman (2003) are likely due to horses grazing the high herbage mass pasture having slower intake rates due to taking larger bites.

2.2.2 Environmental Factors

Environmental factors effecting the domestic animal's ability to maintain food intake and satisfy nutrient demand can be summarised into climatic, seasonal and managerial considerations. Seasonal and climatic fluctuations in temperature, humidity, rainfall, wind speed and solar radiation influence the amount and quality of plants available, and require physiological responses that can affect an animal's ability to search for, consume and utilise available food. Managerial considerations include the effects of group feeding and feeding frequency on grazing and individually managed animals.

Effect of Climate on Plant Availability and Quality

Temperature is highly influential over plant growth. Respectively, ambient temperatures for plant growth of temperate and tropical species range respectively from 5 - 8^{o}C (Broad & Hough, 1993) and 30 – 35^{o}C (Cooper & Tainton, 1968). Plants grown in above ambient temperatures mature at faster rates than those grown at ambient temperature, leading to rapid conversion of soluble cell contents to structural cell wall components, increasing lignification and lowering DMD (Buxton & Casler, 1993). High environmental temperatures also increase stem growth, lowering the leaf:stem ratio, reducing yield, palatability and digestibility (West, 1997). Longer day length and greater light intensity increase photosynthetic activity increasing soluble cell contents (Buxton & Fales, 1994). The UK summer, comprising long days and moderate temperatures, therefore seems to provide ideal conditions for temperate plants to grow, however, unpredictable rainfall is common during UK summers, and can reduce yield or leach nutrients from field dried forages (Buxton & Fales, 1994; McDonald *et al*., 2002). Low temperatures and too little rain can also reduce plant growth and yield through reduced cell enlargement and enzymatic reactions (Buxton & Fales, 1994).

Effect of Climate on Dry Matter Intake by Equids

The effects of climate on food intake are solely related to the maintenance of body temperature in mammals. To maintain core body temperature in climatic conditions decreasing body temperature, mammals must increase heat production, increasing the demands for heat gained from digestion and fermentation, increasing food intake. Conditions increasing body temperature have the opposite effect.

The influence ambient temperature has on food intake has been extensively researched in production animals, however, the amount of data relating to equids is limited. Ruminant animals respond to ambient temperatures above their thermoneutral zone (TNZ) (5 – 25^{o}C) by reducing DMI but increasing mean retention time (MRT) of digesta within the GIT, increasing digestive efficiency (NRC, 1981; Mathers, Baber & Archibald, 1989; Ahmed & El Amin, 1997; West, Mullinix & Bernard, 2003). Decreased rumen motility at high ambient temperatures, thought to be due to a reduction in thyroid function, increases the time digesta remains within the rumen, affecting digestion independently of DMI (Attebery & Johnson, 1969; Warren *et al.*, 1974; Lippke, 1975). Exposure to ambient temperatures below their TNZ increases DMI in ruminants (NRC, 1981). Cold exposure increases thyroid function and digesta passage rate out of the rumen, enabling higher DMI but reducing digestibility (Kennedy, Christopherson & Milligan, 1976; Westra & Christopherson, 1976; NRC, 1981; Kennedy, 1985).

Results from the few studies into the effects of low and high temperatures on DMI and digestive efficiency in equids provide some indication of how climate may affect food intake, however, results are not conclusive. Exposure of desert acclimatised donkeys to ambient temperatures of 40 – 45^{o}C reduced their vDMI of alfalfa hay by 7 – 14%, reducing daily DMI from 1.4% BW (BW not provided) to 1.2% BW (Yousef, 1985). However, acute exposure (12 hours at 22^{o}C followed by 12 hours at 40^{o}C) of donkeys to controlled heat stress in metabolic rooms failed to affect DMI of poor quality hay (108g/kg $BW^{0.75}$), compared to DMI recorded in the control environment when the donkeys were continuously housed at 22^{o}C (109g/kg $BW^{0.75}$) (Maloiy, 1970). Apparent DMD, however, was significantly ($P<0.001$) higher in the heat stressed donkeys compared to those managed at a continuous temperature (51 and 41%, respectively). These results are similar to those found for ruminant animals and indicate a slower rate of passage of digesta through the GIT. The cause of this slower rate of passage does not appear to be a lower food intake. A study by McBride, Christopherson & Sauer (1985) also failed to show any effect of high temperatures on thyroid hormone secretion. When exposed to 18^{o}C for 6 hours, thyroid hormone concentrations in cold acclimatised horses (-4 to -11^{o}C) did not decrease. The absence of any response to higher ambient temperatures by the horses in the study by McBride *et al*., (1985) may have been due to the short exposure time of horses to higher temperatures. In the same study, acute exposure to below ambient temperatures (-10 to -40) also failed to increase thyroid function, however, prolonged exposure to temperatures ranging from -4 to -11 induced a gradual increase in thyroid function as ambient temperature decreased ($P<0.05$). The lack of effect of acute temperature changes on thyroid function was probably due to the thermoregulatory responses of the experimental animals maintaining normal body temperature. Prolonged exposure of yearling colts to ambient temperatures of either -24 to 24°C (cold housed: mean 5.2°C) or 3 to 18°C (warm housed: mean 10.9°C) had no effect on apparent DMD but did increase digestibility of cell wall fractions in the cold housed colts ($P<0.05$) (Cymbaluk, 1990b). However, the greater utilisation of the fibre fraction of the diet by the cold housed colts was not due to a decrease in passage rate as MRT for the two groups of horses did not differ significantly. The processes leading to greater utilisation of the fibrous fraction by the cold housed group are unclear. Further research into the effects of environmental temperature on food intake and digestibility are needed to offer a possible explanation.

Application of these results to the practical situation of feeding donkeys in the UK is of limited use. Mean ambient temperatures in the UK over recent years have ranged between -4.8°C in winter to 22.2°C in summer (Met Office, Devon, UK). Results of most of the studies investigating the effects of extreme temperatures are therefore not applicable to the UK climate. However, ambient temperature can remain below the TNZ of horses (5 to 25°C) (Morgan, 1997) for days or weeks during UK winters and horses may require additional food in response to increased vDMI and faster passage rates. Increasing the amount of DM consumed as forage increases the amount of heat produced through enzymatic digestion and microbial fermentation, helping to maintain internal body temperature. Ambient temperatures in the UK summer season increase gradually and are usually within the TNZ of horses and are therefore unlikely to depress food intake. The TNZ of donkeys in the UK has not been determined, however, an animal's TNZ is influenced by some degree to the acclimatisation to the ambient temperature they have been previously exposed

(Schmidt-Nielsen, 1983) therefore the donkey is likely to have a similar TNZ to horses in the UK.

The effects of ambient temperature on food intake and an animal's ability to maintain body temperature are also influenced by relative humidity, wind, rain and solar radiation. A review of literature to date has found no studies investigating the effects of these factors on DMI by equids, although it is known that high ambient temperatures combined with high humidity increase the heat stress on animals (Cymbaluk & Christison, 1990) due to decreased evaporative losses. In these circumstances DMI would probably be reduced. The effects of wind on body temperature regulation are beneficial in high ambient temperatures but detrimental at low ambient temperatures due to increased cooling from evaporation and convection (Robbins, 2001). During high ambient temperatures rain helps to cool the body whilst solar radiation increases body temperature. During cool ambient temperatures rain will increase heat loss, especially if combined with strong winds, whilst heat from solar radiation will help to maintain body temperature. The effects of these climatic factors on DMI will follow those previously mentioned for equids if food availability allows; factors increasing heat stress will reduce DMI whilst those inducing cold stress will increase DMI.

Effect of Season on Dry Matter Intake and Grazing Behaviour

The effects of season on DMI are related to changes in photoperiod. Photoperiod influences DMI and body weight in a number of species. Red deer (Simpson, Suttie & Kay, 1984; Rhind *et al*., 1998; Webster *et al*., 2000), reindeer (Mesteig, Tyler & Blix, 2000), pigs (Bruininx *et al*., 2002) and cows (Peters *et al*., 1980) increase their vDMI with increasing photoperiod. This response to longer day length is associated with a reduced secretion of melatonin from the pineal gland (Goldman, 2001; Lincoln, Andersson & Loudon, 2003). Melatonin acts on the pituitary gland, suppressing the secretion of prolactin (Robinson *et al*., 1992; Goldman, 2001). In periods of light, melatonin secretion is suppressed, increasing prolactin secretion. In periods of darkness, prolactin secretion decreases due to increased melatonin secretion. Prolactin is associated with higher DMI and increases in body weight, and is therefore thought to be the principle promoter of higher DMI during longer photoperiods (Moore *et al*., 1986; Byatt *et al*., 1993; Sauve & Woodside, 1996; Rhind *et al*., 1998). Increased prolactin concentrations in summer, compared to winter, have also been reported in horses (Thompson *et al*., 1986; Thompson & Johnson, 1987), indicating the same effect of photoperiod on DMI by equids, although the direct effect of photoperiod has not been investigated in equids.

Season also influences grazing behaviour of equids. Behaviour studies of domestic and semi-wild horses in temperate climates show shorter grazing times during the summer and longer grazing times during autumn (Menard *et al*., 2002), winter (Lamoot & Hoffmann, 2004) and spring (Berger *et al*., 1999). In the studies by Menard *et al*. (2002) and Lamoot and Hoffmann (2004), the longer grazing times in autumn and winter coincided with increased grazing of poor quality plants. During summer the shorter grazing times coincided with increased grazing of productive plant species. The longer day lengths, and greater nutritional quality and availability of pastures during spring and summer seasons, therefore appear to promote DMI and increasing body weight.

Managerial Factors

Feeding Method

The feeding of a calculated ration enables owners to regulate their animal's intake and prevent malnutrition or obesity, if balanced correctly. Correctly calculated rations remove the need for animals to regulate intake as the required nutrients and energy are provided within DMI limits. As rations are formulated from energy and nutrient requirements on a bodyweight basis, it is essential that the current body condition and the desired body condition of the animal are used to calculated energy and nutrient requirements. An undesired loss of bodyweight would result in smaller rations being fed if just the current bodyweight was used, when the animal actually has increased energy and food requirements to enable it to gain bodyweight. Identifying the desired increase in bodyweight enables the ration to be increased. Calculated rations are usually fed to equids as individual meals of measured quantity given at specific times each day. The effect of meal frequency on DMI in equids has not been studied.

Animals fed *ad libitum* must regulate their own intake to ensure energy and nutrient requirements are met within their daily DMI limit. Current recommendations are to feed equids 15 – 25g DM per kg BW (NRC, 2007) to satisfy DMI requirements. Studies into the vDMIs of forages by stabled horses, ponies and donkeys report intakes within this range (Table 2.2). Voluntary intakes above the recommended range are predominantly from animals consuming alfalfa hays due to the shorter handling and processing time of legume hays compared to grass and straw forages. The exceptions to this trend were the higher intakes by donkeys and ponies of a more fibrous, poor quality hay, compared to intakes of a good quality hay, reported by

Tisserand *et al*. (1990). The lower intakes of the good quality hay however were attributed to lack of adaptation to the study area by the study animals, resulting in the donkeys and ponies consuming less of the first diet fed (good quality hay).

Table 2.2. Mean voluntary dry matter intake (vDMI g/kg BW) by donkeys, ponies and horses fed different forage diets

Animal (*n*)	Diet	DMI (g/kg BW)	Reference
Donkeys			
3	Cocksfoot hay (good quality)	12	Tisserand *et al*. 1990
3	Cocksfoot hay (poor quality)	22	
5	Grass hay (poor quality)	18	Mueller *et al*. 1994
5	Grass/legume hay	19	
6	Hay (poor quality)	16 – 25	Nengomasha, Pearson & Smith, 1999
4	**Alfalfa hay** (chopped)	**27**	Pearson *et al*. 2001
4	Oat straw (chopped)	16	
6	Sorghum fodder (chopped) †	13 – 29	Ram *et al*. 2004
12	Hay (poor quality)	20	Smith *et al*. 2007
Mean		*20*	
Ponies			
3	Cocksfoot hay (good quality)	15	Tisserand *et al*. 1990
3	**Cocksfoot hay** (poor quality)	**27**	
4	**Alfalfa hay** (chopped)	**39**	Pearson *et al*. 2001
4	Oat straw (chopped)	24	
Mean		*26*	
Horses			
6	**Alfalfa hay**	**27**	Cymbaluk, 1990a
6	**Matua bromegrass hay** (chopped)	**27**	
6	Kentucky bluestem hay (chopped)	20	
6	Oat hay (chopped)	19	
6	**Alfalfa hay** (chopped)	**28**	Crozier *et al*. 1997
6	Tall fescue hay (chopped)	25	
6	Caucasian bluestem hay (chopped)	23	
6	**Alfalfa hay**	**31**	LaCasha *et al*. 1999
6	**Matua bromegrass hay**	**28**	
6	Coastal bermudagrass hay	23	
Mean		*25*	

† Fed sorghum fodder *ad libitum* plus 1kg concentrates
Voluntary DMI highlighted in bold are above DM feeding recommendations for horses according to NRC (2007)

The higher intakes of less fibrous forages are evidence that the equine appetite can exceed the recommended DMI, and that when intake is not limited by rate of consumption, equids will continue to eat despite satisfying DMI and DE requirements. Based on results from feeding a high fibre concentrate feed, Cuddeford & Hyslop (1996) proposed that over short time periods stabled equids do not regulate their intake. A recent study by Argo *et al*. (2002) suggests that over longer periods of *ad libitum* feeding equids may regulate their DMI after an initial increase in food intake. Over a study period of 4 weeks the vDMI of two groups (n=4) of ponies fed a fibre based complete diet in either chaff or pellet form were measured. After 4 weeks the diet forms offered to each group were swapped and vDMI measured for a further 4 weeks. Voluntary DMI increased throughout the first 4 weeks for ponies in both groups. An effect of dietary form was seen in the ponies swapped from the pelleted to the chaffed form, with DMI declining rapidly during the first week, although during the remaining 3 weeks intake remained relatively constant. Ponies receiving the pelleted form in the second study period would be expected to increase intake due to the faster intake rate of pelleted feeds. An initial increase in intake was recorded during the first week, although DMI decreased thereafter. Ponies in both groups consumed DE in excess of requirements during the first 4 week period. During the second 4 week period DEI in all ponies stabilised, meeting DE requirements for maintenance. Although not conclusive, the regulation of food intake by stabled equids in the study by Argo *et al*. (2002) suggests that given time to adjust, *ad libitum* feeding is a suitable method for managing equids although the initially high intakes increase the risk of animals suffering from colic and laminitis. If equids do not regulate their intake when stabled the potential for excess energy intake is greater when feeding low fibre forages *ad libitum*. This is advantageous when aiming to increase energy and nutrient intake without feeding concentrates. The limited intake of more fibrous forages is also advantageous in restricting energy intake, and offers owners a way of limiting intake without having to feed measured quantities of food that could reduce total food offered and daily feeding time.

Group Feeding

To date there has been very little research into the affects of group feeding on DMI by equids, although behaviour studies on horses indicate there would be an affect of social interaction on feeding behaviour. Ellard and Crowell-Davis (1989) and Weeks *et al*. (2000) report social hierarchy in group managed horses, and observed dominant animals having priority over food resources. The authors concluded that in group feeding situations low ranking individuals would have difficulty accessing food, especially if administered in small feeding areas, and that in these circumstances nutritional needs may not be met. Studies into ruminant animals fed in groups show that group feeding may actually increase food intake through the effect of social facilitation. Social facilitation increases an animals desire to eat and (Curtis & Houpt, 1983) promotes feeding in dairy cows (Grant & Albright, 2001) and lambs (Jenkins & Leymaster, 1987) leading to higher intakes. However, an animal's ability to satisfy it's desire to eat is influenced by the competition for food. Competition for food increases when the number of animals sharing the feeding area increases and when available food resources become low. In such circumstances low ranking animals may be prevented from eating by dominant animals, reducing DMI.

Social facilitation has also been observed in ponies. Time allocated to feeding by ponies fed a hay diet was increased when allowed visual contact with an adjacently housed pony that was also eating (Sweeting, Houpt & Houpt, 1985). Feeding time when fresh hay was offered in the morning was not affected by visual contact, however, time allocated to feeding in the afternoon was significantly ($P<0.05$) lower in ponies when prevented from seeing adjacently housed ponies eating compared to when visual contact was possible (60 and 73% of observation time allocated to feeding, respectively). The increased feeding time when visual contact was possible was thought to be due to stimulation to eat from adjacent animals eating, as rates of simultaneous eating bouts decreased by 10% when visual contact was prevented despite continued auditory and olfactory stimulation. These results were for ponies housed individually, however, if social facilitation continues to exert an affect on equine feeding behaviour when they are managed in a group or when grazing, higher DMI may be gained, although expression of this stimulated feeding behaviour will be dictated by food availability, feeding space and hierarchy.

Grazing Access

Commonly, domestic equids in the UK are managed with access to grazing for all or part of the day. The affects of different grazing routines and practices on DMI by donkeys, ponies and horses are relatively unknown due to difficulties in accurately measuring DMI in the field, although the effect of grazing time on intake by ruminant animals and donkeys has been investigated. Results from studies using ruminant animals and equids have shown increased grazing times in response to grazing shorter pastures, compared to grazing times when restricted to taller pastures (Allden & McDWhittaker, 1970; Rook, Huckle & Penning, 1994; Gekara *et al.*, 2001; McMeniman, 2003). McMeniman (2003) reported similar vDMI by weanling horses (15, 15 and 16g DM/kg BW) when grazing pastures of different height (52, 58 and 69 cm tall, respectively), despite increased grazing times on the shorter pastures (10.2, 9.3 and 7.9 hours, respectively [P>0.05]). Increasing grazing time would enable some degree of compensation for decreased bite depth and weight incurred on shorter pastures, although this compensatory mechanism will be limited by the maximum time available to graze, dictated by pasture access time. Results from sheep and donkeys support the findings of McMeniman (2003). Iason *et al*. (1999) found that sheep increased bite weight (P>0.05), bite rate (P>0.05) and intake rate (g/minute) (P<0.05) when restricted to approximately 5.5 hours grazing per day compared to when allowed continual grazing access, but this increase was unable to fully compensate for the shorter grazing time resulting in lower DMI (g/kg $BW^{0.75}$) when grazing time was restricted (P<0.01). Smith (1999) undertook a comprehensive study into the grazing behaviour and DMI of cattle and donkeys in Africa. One study investigated the affect of restricting donkeys and cattle to 8 and 11 hours grazing time per day compared to 23 hours grazing access. The effect of herbage availability during different seasons was also determined. When herbage mass was greater, but pasture was of poor quality (end of the dry season), restricting daily grazing access to 11 hours or less significantly reduced DMI by the donkeys (g/kg $BW^{0.75}$) (P<0.001). The quality of the diets selected by the donkeys in the 11 and 23 hour grazing groups were similar, however, the quality of the diet selected by the 8 hour group was significantly lower than that selected by the donkeys with 23 hours grazing access (P<0.01). Results from bite measurements show that the donkeys restricted to 8 hours grazing per day became less selective, increasing bite rate and bites per step in an attempt to increase DMI but at the expense of diet quality. When pasture was of better quality but lower herbage mass (middle of the wet season) restricting grazing time had the same affect on DMI as when herbage mass was greater. Donkeys restricted to 11 hours grazing or less had significantly lower DMI than those with 23 hours access (P<0.001). Diet quality and bite rate did not differ significantly between grazing groups, although bite size was significantly greater in the donkeys restricted to 8 hours grazing compared to those in the 23 hour group (P<0.01). The combination of larger bite size and a slightly faster bite rate resulted in significantly faster intakes rates by the 8 hour group of donkeys compared to the 23 hour group (P<0.001). The faster intake rates of donkeys restricted to 8 hours grazing per day resulted in DMI similar to those of donkeys restricted to 11 hours per day, but were unable to compensate for the difference in pasture access time between the 8 and 23 hour grazing groups. The higher quality of the pasture in the wet season and the similar quality of diets consumed by donkeys, regardless of grazing group, indicates that donkeys select for a better quality diet if food resources allow, and that some degree of compensation is possible by increasing bite size. Decreasing grazing time to 8 hours per day affected DMI and bite dimensions to a greater extent than restricting donkeys to 11 hours per day. Attempts to reduce pasture intake via restricted grazing time therefore need to limit donkeys to less than 11 hours grazing access per day.

2.2.3 Animal Factors

An animal’s body size affects DMI by limiting the capacity of the GIT. Mouth size and anatomy also affect an animal’s ability to satisfy nutrient requirements via its affect on diet selection. Gut capacity and diet selection in turn influence digesta passage rate and retention time with these factors affecting digestive efficiency. Combined, these factors influence feeding behaviour and lead to animals adopting specific feeding strategies in order to satisfy energy and nutrient requirements.

Biometric Measurements

Body Size and Gastrointestinal Tract Capacity

Metabolic rate is the major determinant of food intake (Demment & Van Soest, 1985). Resting metabolic rate and thus energy requirements are proportional (0.75) to body weight, increasing nonlinearly with body weight (Brody, 1945; Kleiber, 1975; Demment & Van Soest, 1985). In contrast, GIT capacity increases linearly with body weight (Demment, 1982), thus larger animals have lower maintenance energy requirements but greater GIT capacities per kilogram of body weight compared to smaller animals. The greater GIT capacity of larger animals enables digesta to be retained in the GIT for longer, increasing exposure of plant material to enzymatic and microbial populations, increasing diet utilisation and digestibility, and reducing DMI per unit of body weight (Demment & Van Soest, 1985; Van Soest, 1996).

According to the principles described above, relating metabolic rate and GIT capacity to body size, the smaller size of donkeys compared to horses should result in shorter retention times and higher DMI compared to horses. Studies of equine passage rates show that mean retention times of donkeys are significantly longer than those of horses and ponies fed the same diets (Pearson & Merritt, 1991; Cuddeford *et al*., 1995; Pearson *et al*., 2001). Why and how donkeys are able to retain digesta within the GIT longer than horses despite being of smaller size has not been investigated. Desert adapted Bedouin goats have longer retention times and greater digestive efficiency compared to larger, temperate goat breeds (Swiss Saanen goats) (Silanikove, Tagari & Shkolnik, 1993). The longer retention times are thought to be an adaptation to the limited food supply available to the goats in their natural habitat, requiring greater utilisation of food resources. The arid environments in which the donkey evolved are likely to have evoked a similar digestive strategy to low food availability. How donkeys and goats are able to retain digesta for longer if their smaller body size reduces their GIT capacity is not fully understood. Slower passage rates are generally associated with lower DMI in ruminants, however, Silanikove *et al*. (1993) reported similar DMI by Bedouin and Swiss Saanen goats, indicating that the GIT capacity of the desert adapted goats was greater than that of the temperate breed. A study into the internal anatomy of native Japanese Hokkaido ponies (BW 191 $\pm$ 28kg) and Thoroughbred horses (BW 562 $\pm$ 30kg) revealed the caecum and colon comprised a greater percentage of total body weight and digestive tract weight in the native ponies compared to the horses (Kobayashi *et al*., 2006). Retention times were not measured. Hokkaido ponies are traditionally managed outdoors all year round (Shingu *et al*., 2000). As a result, they are adapted to browse on bark and twigs during winter when snow prevents grazing. The larger caecum and colon of Hokkaido ponies indicate greater adaptation to this fibrous diet compared to Thoroughbred horses. Donkeys, evolving in harsh environments, may also have developed a larger GIT capacity, increasing retention times and thus digestive efficiency. Comparison of the GIT anatomy of donkeys, horses and ponies is needed to confirm this hypothesis.

Mouth Size

The size of an animal's mouth influences the degree of selectivity that the animal is able to exhibit (Hanley, 1982). A smaller mouth is able to select specific plant parts or species whilst avoiding undesirable material. To date no research comparing equine mouth dimensions between breed and species has been undertaken, therefore the degree of selectivity exhibited by equids due to mouth size is unknown. Herbivore animals utilising browse are generally more selective in which part of the plant eaten, selecting for the more nutritious parts and avoiding the more fibrous parts (Hofmann & Stewart, 1972; Shipley, 1999), although plant species classified as browse are generally of lower nutritional value than grass species (Van Soest, 1996). Studies into behaviour, diet and habitat selection by grazing donkeys, horses and ponies have shown that horses and ponies do utilise browse, although this behaviour is mainly expressed when intake of grass species is reduced (Putman *et al*., 1987; Moehlman, 1998; Lamoot & Hoffmann, 2004). In contrast, donkeys have been observed to browse on trees and shrubs even when food resources were abundant (Rutagwenda *et al*., 1990; Moehlman, 1998). This ability to utilise these additional food sources is thought to be due to increased upper lip mobility in the donkey compared to the horse and pony (Moehlman, 1998). In the domestic situation this increased selectivity would place donkeys at an advantage when offered diets *ad libitum*, enabling selection of more nutritious plant species and plant parts. Domestic grazing donkeys will also browse on hedges even when grazing is abundant (personal observation). The ability of donkeys, and to a lesser extent horses and ponies, to utilise browse, increases the choice of plant species available to eat. In winter, when availability of grass species is reduced, increasing browse intake helps to maintain DMI and satisfy nutrient requirements.

Digesta Passage Rate and Digestive Efficiency

Passage rate is defined as the flow of digesta through the entire GIT per unit of time (Robbins, 2001). Measuring passage rate, using indigestible markers, enables retention time of digesta within the GIT to be calculated. Mean retention time is the average time between marker administration and faecal excretion.

Digesta passage rate is affected by GIT structure. In ruminant animals passage rate is influential over DMI due to restricted flow of large particles through the reticulo-omasal orifice (Poppi *et al*., 1980; Shaver *et al*., 1986; Oshita *et al*., 2004). In contrast, passage of digesta along the equine GIT is not restricted by particle size until it reaches the large intestine. Within the large intestine numerous compartments and flexures aid in the mixing of digesta and control flow through the remainder of the GIT. The caecum, ventral colon and the junction between the ventral and dorsal colon (pelvic flexure) are thought to restrict the flow of larger particles (>10mm), whilst the boundary between the dorsal and distal colon selectively retains liquid and fine particles (<2mm) (Drogoul, Poncet & Tisserand, 2000). Despite these mechanisms, particles up to 1.6mm in length are able to pass through the equine GIT (Uden & Van Soest, 1982b), thus, in equids, DMI and diet are influential over passage rate.

Evidence of these differences between ruminant animals and equids come from studies by Uden *et al*. (1982), Uden and Van Soest, (1982b) and Sponheimer *et al*. (2003). Uden *et al*. (1982) calculated MRT in ruminants (heifers, sheep and goats), equids (horses and ponies) and rabbits fed Timothy hay *ad libitum*. Comparison of

MRT of solid phase particles between the horses and ponies and larger ruminants show considerably shorter retention times in the horses and ponies (BW 95 – 500kg) compared to the heifers (220 – 610kg) (23 hours vs. 58 hours, respectively). Apparent digestibility of plant cell wall fractions in the same study were reported by Uden and Van Soest (1982b). The shorter retention time of digesta within the equine GIT resulted in lowest cell wall and DM digestibilities compared to all the ruminant species. The faster passage rate, and thus less efficient digestion of the fibrous fractions, was due to the higher DMI (g/kg $BW^{0.75}$) by the horses and ponies compared to all ruminant animals. Similar differences in DMI and DMD between horses and ruminants (goats, alpacas and llamas) were also reported by Sponheimer *et al*. (2003).

Comparisons of passage rates between horses, ponies and donkeys show digesta passes through the donkey GIT at a slower rate (Table 2.3). Pearson and Merritt (1991) offering meadow hay and barley straw diets *ad libitum* found donkeys had significantly longer MRT of solid ($P<0.001$) and liquid ($P<0.01$) phase particles when fed both diets compared to the ponies. These results were repeated in a study by Pearson *et al*. (2001) in donkeys consuming oat straw and alfalfa hay *ad libitum*. In both studies the donkeys consumed significantly less DM ($P<0.01$) but digested all analytic fractions (DM, gross energy [GE], ADF, NDF, organic matter [OM], crude protein [CP]) more efficiently. Cuddeford *et al*. (1995), feeding to calculated energy requirements, also reported longer ($P<0.01$) solid phase MRT and higher ($P<0.01$) OM, GE, ADF and NDF digestibilities by donkeys compared to Thoroughbred horses, Highland ponies and Shetland ponies fed alfalfa hay and oat straw in varying proportions. In each of these studies, MRT in all experimental animals were longer and vDMI lower when fed fibrous forages, leading to greater apparent ADF and NDF digestibility. These results support the theory that passage rate and digestive efficiency are a consequence of DMI and diet quality, but do not support the theory proposed by Janis (1976). Janis (1976) proposed that when offered foods of low quality, equids increase their DMI, and thus passage rate, to maintain intake of soluble nutrients, but at the consequence of microbial fermentation. Cuddeford *et al*. (1995) stated that their results support the theory proposed by Janis (1976) as all animals had higher DMI on a body weight basis when fed the fibrous straw diets compared to when fed the alfalfa hay diet. These results however reflect the lower energy density of the straw diets, hence greater amounts of straw were offered to meet calculated energy requirements. The lower vDMIs by donkeys and ponies receiving straw diets compared to when receiving diets of alfalfa and meadow hay in the studies by Pearson and Merritt (1991) and Pearson *et al*. (2001) also oppose the theory by Janis (1976). Although the lower intakes may have been the result of slower intake rates preventing any increase in DMI in response to lower nutritive value.

Table 2.3. Mean voluntary dry matter intake (vDMI g/kg $BW^{0.75}$) and mean retention time of solid phase particles within the gastrointestinal tract (GIT) of ponies and donkeys fed different forage diets

Diet	**DMI (g/kg $BW^{0.75}$)**		**MRT of Cr-fibre (hours)**		**Reference**
	Donkey	Pony	Donkey	Pony	
Meadow hay (*ad lib*)	81	99	37.9	29.9	Pearson & Merritt, 1991
Barley straw (*ad lib*)	37	60	53.9	34.8	
Alfalfa *	40	40	76.7	46.3	Cuddeford *et al.* 1995
Oat straw *	56	49	53.8	46.9	
Alfalfa (chopped) (*ad lib*)	100	155	32.8	21.3	Pearson *et al.* 2001
Oat straw (chopped) (*ad lib*)	60	95	44.3	31.5	

* Fed to calculated maintenance energy requirements

Cuddeford *et al*. (1995) proposed that donkeys retain digesta within their GIT for longer than horses and ponies, regardless of DMI. This theory was based on the higher DMI but longer MRT by donkeys compared to Shetland ponies. Dry matter intake did not appear to influence passage rate in the donkeys as it did in the horses and ponies. Although not calculating passage rate, results from a study by Tisserand *et al*. (1990) support this theory, showing a greater affect of diet and DMI on digestibility in ponies, compared to donkeys, when feeding different forages. Analysis of forage refused in the study showed donkeys selected against fibre when fed the straw diets, indicating that the more efficient digestion of this diet by the donkeys compared to the ponies was partly due to selection of a better quality diet by the donkeys (Tisserand *et al*., 1990).

Analysis of degradation rates by donkeys, ponies and ruminants have also shown that donkeys degrade plant cell wall components at a faster rate and to greater extent than ponies when fed good quality and poor quality forages. Julliand *et al*. (1997) compared NDF degradation in the caecum of donkeys and ponies and the rumen of cows consuming wheat straw and lucerne-orchardgrass hay. Neutral-detergent fibre degradation was greater in both donkeys and ponies compared to the cows in the first 8 hours post feeding when offered the wheat straw diet. However, from 8 hours onwards the cows were more efficient at digesting the NDF fraction, and by the end of the 48 hour incubation period, ruminant degradation efficiency was significantly ($P<0.05$) greater than that of the equids, being almost double that of the donkeys and ponies. Neutral-detergent fibre digestibilities after 48 hours incubation for the donkeys, ponies and cows were 26, 24 and 43%, respectively. When offered the better quality hay diet, significant differences in total NDF digestibility and degradation rate between the donkeys and ponies were apparent. For the first 8 hours post feeding the donkeys degraded significantly more NDF than the ponies and similar amounts to the cows (NDF digestibility 8 hours post feeding; 30, 21 and 31% for donkeys, ponies and cows, respectively). However, from 16 hours onwards the cows showed significantly greater NDF digestibility than both the donkeys and ponies ($P<0.05$), although the donkeys were intermediate between these two species. Total NDF digestibility after 48 hours incubation was 46, 41 and 55% for donkeys, ponies and cows, respectively. The differences in NDF degradation rates between equids and ruminants in the first 8 hours incubation reported by Julliand *et al*. (1997) may have been the result of faster growth of cellulose degrading fungi (*Piromyces citronii*) and greater utilisation of cellulose by this fungi in the equine caecum, compared to that found in the rumen (*P. communis*) (Julliand *et al*., 1998). Julliand *et al*. (1998) also found faster growth rates of *P. citronii* and greater degradation of cellulose in the donkey caecum compared to fungi isolated from the caecum of ponies. From these results, and those from the other studies highlighted here, it seems that the greater digestive efficiency of the donkey is due to a combination of prolonged retention time, greater digestive efficiency of the fibrous fraction within the donkey's caecum, and increased selective behaviour when offered high fibre diets. These factors place the donkey at an advantage to other domestic equids when food is of limited availability and of poor quality.

Feeding Strategy of the Donkey

Food Selection

Plant selections by grazing equids appear opposite to these reported for stabled equids, where legume forages are selected in preference to grass forages (Crozier *et* *al*., 1997; LaCasha *et al*., 1999). During the summer grazing season (April – September), grazing horses were observed to prefer grass species over legume species (Archer, 1973), however, results from studies by Hunt (1995) showed plant selection by grazing horses in New Zealand changed with plant species' growth and availability. Grass species were favoured in winter and spring when legume growth was minimal, but when legume growth increased during the summer and autumn, intake of legume species increased with a consequential decrease in the intake of grasses. Results from Putman *et al*. (1987) and Gordon (1989) support the findings by Hunt (1995) that plant selection changes with plant availability and nutrient content. Putman *et al*. (1987) reported significant positive correlations between plant intake and plant productivity and digestibility in grazing ponies in the New Forest. Seasonal plant availability also influenced plant selection by grazing donkeys in Kenya (Rutagwenda *et al*., 1990). During the wet season when availability of more nutritious plants increased, donkeys selected to eat plants of greater nutritive value. During the dry season the time donkeys spent grazing poor quality plants increased as food resources decreased (Rutagwenda *et al*., 1990), presumably as an attempt to maintain DMI when food resources were reduced. The higher intake of nutritious plants as they become available indicates that plant species *per se* is not the most important factor in plant selection. When food availability does not limit intake equids seem to select for nutrient content, however, under grazing conditions plant availability is the primary influencing factor of plant selection (Salter & Hudson, 1979; Gordon, 1989).

Feeding Strategy

Results from passage rate and digestibility studies show how equids are able to cope with fibrous foods. Compared to ruminant animals, equids have developed a strategy of higher DMI per unit of body weight, faster passage of digesta through the GIT and lower digestive efficiency of fibrous material. Such a strategy is advantageous when fed poor quality, high fibre forages, as increasing DMI increases the amount of soluble and structural cell components for digestion, maintaining nutrient absorption per unit of time despite reduced microbial fermentation (Janis, 1976). *Ad libitum* feeding therefore enables the equid to maximise this strategy. When food sources are restricted, an increase in DMI is prevented, placing equids at a disadvantage compared to ruminants.

The strategy of the donkey appears intermediate to that of horses and ponies and ruminants. Dry matter intakes on a body weight basis are higher than those of ruminants but lower than those of horses and ponies (Tisserand *et al*., 1990; Pearson & Merritt, 1991; Pearson *et al*., 2001). The lower DMI and slower passage rates of the donkey increase fibre digestion, increasing nutrient and energy intake per unit of food consumed, particularly from cell wall components. Such a feeding strategy is probably an adaptive mechanism for survival in arid, desert environments from where the donkey originated.

2.2.4 Voluntary Dry Matter Intake by Donkeys

Voluntary DMI by donkeys have been reported in a number of studies. Donkeys receiving all forage diets had vDMI ranging from 37g to 100g per kilogram of metabolic body weight (Table 2.4).

Table 2.4. Mean neutral-detergent fibre (NDF g/kg DM) content and voluntary dry matter intake (vDMI g/kg $BW^{0.75}$) by donkeys fed different forages (Smith & Pearson, 2005)

No. of animals	BW (kg)	Diet	Feeding Level	Forage NDF content (g/kg DM)	DMI (g/kg $BW^{0.75}$)	Reference
2	100	Oat straw	1.2 * M	708	77	Butterworth *et al*. 1987
		Meadow hay	1.2 * M	695	92	
3	250	Cocksfoot hay (good quality)	*Ad libitum*	†	48	Tisserand *et al*. 1990
		Cocksfoot hay (poor quality)	*Ad libitum*	†	88	
		Molassed straw	*Ad libitum*	†	57	
4	179	Meadow hay	*Ad libitum*	737	81	Pearson & Merritt, 1991
		Barley straw	*Ad libitum*	886	37	
5	198	Grass hay (poor quality)	*Ad libitum*	662	67	Mueller *et al*. 1994
	197	Grass/legume hay	*Ad libitum*	616	72	
4	155	Hay (poor quality)	*Ad libitum*	780	75	Nengomasha *et al*. 1999
4	197	Molassed alfalfa hay	*Ad libitum*	443	100	Pearson *et al*. 2001
	182	Molassed oat straw	*Ad libitum*	715	60	
6	142	Sorghum fodder plus Concentrate	*Ad libitum* 1kg	†	80	Ram *et al*. 2004

†: NDF value not provided
M: Maintenance DMI

The wide range of DMI reflects differences in forage palatability, handling time and intake rate. When receiving more digestible, energy dense forages such as alfalfa hay, DMI averaged 86g/kg $BW^{0.75}$. In contrast DMI of the straw diets averaged 58g/kg $BW^{0.75}$. Intakes of grass hays were intermediate between these two values (75g DM/kg $BW^{0.75}$). The higher intakes of the alfalfa hays reflect a greater palatability and shorter handling time of this forage compared to that of the straw. Donkeys receiving molassed alfalfa hay in the study by Pearson *et al*. (2001) had the highest intakes reported in all the studies (100g DM/kg $BW^{0.75}$). These high DMI resulted in the donkeys gaining weight, indicating that they were consuming energy in excess of maintenance requirements. In contrast, when consuming lower energy diets, such as grass hay in the study by Mueller *et al*. (1994), donkeys were able to maintain body weight when consuming similar quantities (92g/kg $BW^{0.75}$) to that which had resulted in weight gain when fed molassed alfalfa hay in the study by Pearson *et al*. (2001).The increased handling time and lower digestibility of the hay reduces the amount of DE gained per unit of food consumed, with total DEI restricted by DMI limits. In all studies feeding straw, except that by Pearson *et al*. (2001), donkeys lost weight when receiving the straw diets. However, Pearson *et al*. (2001) attributed the maintenance of body weight by the donkeys in their study to increased gut fill and not satisfaction of maintenance energy requirements. Therefore, the feeding of straw and hay forages seem suitable for feeding to none working donkeys, enabling DMI requirements to be satisfied without consuming excess energy. Combination of results from all the studies highlighted in Table 2.4 indicate that vDMI by donkeys is approximately 72g per kilogram of metabolic body weight, although this will be influenced by composition of the diet offered.

Comparison of DMI by donkeys with current recommendations for horses and ponies show similarity. Horse rations are recommended to comprise 15 – 25g DM per kilogram body weight (Frape, 2004). Results from the studies in Table 2.4 show an average DMI of 20g/kg BW for donkeys. It appears that donkeys and horses have similar appetites, however results from a recent study by Carretero-Roque *et al*. (2005) indicate that donkeys have lower energy requirements in comparison to horses and ponies.

2.2.5 Summary of Dry Matter Intake by Donkeys

The feeding strategy of the donkey is representative of the environment in which it originated. Compared to the horse, the donkey has adopted a strategy of lower DMI and greater utilisation of digesta via longer retention times (Pearson and Merritt, 1991; Cuddeford *et al*., 1995; Pearson *et al*., 2001) and faster degradation rates (Julliand *et al*., 1997; Julliand *et al*., 1998). When housed and fed to unrestricted levels, donkeys selected a better quality diet than ponies, increasing intake of soluble cell contents and nutrient gain per unit of food consumed (Tisserand *et al*., 1990). These results show adaptation by the donkey to available food sources and highlight the importance of regulating both the amount of food and type of diet fed to donkeys. Unrestricted feeding of high quality, palatable forages, such as alfalfa, lead to increases in body weight. Diets comprising low energy, high fibre forages are most suitable for feeding to donkeys to prevent weight gain and enable natural feeding behaviour. Prevention of weight gain in grazing donkeys requires further research as the affects of stocking density on DMI by donkeys are unknown. Restricting grazing time to less than 11 hours a day seems to reduce DMI although pasture quality and availability will influence the donkey's ability to compensate for shorter grazing times. In addition, utilisation of browse species within or adjacent to grazing pasture will increase DMI even if grazing is limited.

The influence of climate and season on grazing behaviour and plant availability also affect DMI by grazing animals. The greater nutritional quality and increased plant availability during spring and summer, promote higher DMI whilst reducing energy demands for thermoregulation and daily grazing time, and thus activity levels, increasing the likelihood of donkeys becoming overweight.

Prevention of obesity in donkeys requires feeding the same amount of energy as that which is utilised during daily activity, within the donkey's normal appetite range. Voluntary DMI by donkeys seem to be similar to those of horses and ponies, however, the lower maintenance DE requirements of donkeys in Mexico reported by Carretero-Roque *et al*. (2005), combined with the prominence of overweight donkeys in the UK, indicates that the energy requirements of donkeys are lower than those of horses and ponies. If this is the case, feeding diets of lower energy density to donkeys will enable vDMI to be satisfied without overfeeding energy. It is therefore essential to calculate the maintenance energy requirements of donkeys in the UK.

2.3 MAINTENANCE ENERGY REQUIREMENTS

The primary determinant of an animal's daily energy requirement is metabolic rate (Kleiber, 1975), with metabolic rate being related to body weight. Metabolic rate increases nonlinearly with body weight, to the power of 0.75 (Blaxter, 1989). An animal's body weight proportional to the power of 0.75 is referred to as the animal's metabolic body weight. Metabolic body weight is used to compare metabolism between species to account for differences in body size. The scaling of metabolic rate to body weight results in larger animals requiring less energy per unit of body weight compared to smaller animals (Kleiber, 1975; Demment & Van Soest, 1985). Environmental and animal factors inducing changes in metabolic rate therefore change an animal's energy requirement.

2.3.1 Environmental Factors

Effect of Climate on Digestible Energy Requirements

Climatic conditions causing changes in metabolic rate will increase an animal's energy demands. In cold environments that promote loss of body heat, metabolic rate must increase to maintain body temperature. Metabolic rate decreases as ambient temperature increases until the ambient temperature rises above that in which the animal is able to lose body heat (upper critical temperature). In these circumstances metabolic rate increases due to increased heat loss activities such as sweating and increased respiration (Kleiber, 1975). Climatic conditions in the UK are unlikely to exceed the upper critical temperature of donkeys, therefore any climatic affects on energy requirements will be related to cooler ambient temperature. Determining the affects of climate on energy requirements in equids, however, is difficult due to the dearth of information available. To date, the only studies investigating the affects of climate on metabolism and food intake in donkeys, exposed experimental animals to desert conditions (Yousef & Dill, 1969; Yousef, 1985), making results inapplicable to the UK climate. No studies have calculated the additional energy cost for thermoregulation when exposing donkeys to low ambient temperatures, although Yousef (1985) reported an increase in resting metabolic rate when exposed to ambient temperatures below 10^{o}C in donkeys acclimatised to environments between 25 and 37^{o}C.

Results from horses show an increase in maintenance energy requirements when exposed to temperatures below their thermoneutral zone. McBride *et al*. (1985) calculated that when acutely (6 hours) exposed to low ambient temperatures (0 to -40^{o}C), mature horses required an extra 3.4kJ DE per kilogram of body weight for every degree Celsius drop in ambient temperature below the horses lower critical temperature. Similarly, Cymbaluk (1990b) found maintenance DE requirements increased from 0.11MJ to 0.14MJ per kg BW in growing horses when managed at cold (-5.2^{o}C) compared to warm (10.9^{o}C) ambient temperature. The author concluded that for each degree Celsius drop below zero, maintenance DE requirements in growing horses increases 1.3%.

The effects of low ambient temperatures on donkey DE requirements are likely to be increased when combined with the effects of rain and wind. Unlike the coats of horses and ponies, the coats of donkeys are not water resistant. Booth (1998) showed the effectiveness of a water proof winter coat on maintaining body temperature in Shetland ponies. After wetting ponies to the skin, the insulation value of the wet coat was significantly reduced ($P<0.05$). As a result, the ponies decreased skin surface temperature to reduce the amount of heat lost via convection. Metabolic rates of the Shetland ponies were not affected by wetting of the coat although ambient temperatures throughout the study (2 – 9.5^{o}C) were within the ponies' TNZ. When exposed to wet and windy weather, the reduced insulation provided by a wet coat would increase metabolic rate. Exposure to wet weather would therefore increase the maintenance DE requirements in donkeys, compared to horses and ponies, by a greater degree due to the donkey's coat not being water resistant.

Effect of Season on Digestible Energy Requirements

The effect of season on DEI's by equids has not been investigated. Results from grazing studies indicate that equids increase their food intake in summer when food is more abundant and of greater nutritional quality. It can therefore be assumed from the higher intake of more nutritious foods in summer, that intake of energy also increases during summer, with changes in body weight recorded from free ranging Przewalski horses supporting this hypothesis (Scheibe & Streich, 2003). Over a six year period, Scheibe and Streich (2003) recorded changes in body weight of a herd of female Przewalski horses managed in a semi-natural environment in Berlin, Germany. Body weight showed a clear circannual rhythm, reaching a maximum in autumn (September and October) and a minimum in spring (March to May). Berger *et al*. (1999) carried out behavioural studies in the same group of horses and found that grazing activity was maximum in April but lowest in June ($P<0.05$), grazing activity was also high in October. The longer grazing periods in April would have coincided with spring grass growth (herbage availability and quality not reported). The increased availability of young grasses would have enabled horses to graze for longer and satisfy energy and nutrient requirements resulting in the gradual increase in body weight observed in the horses over the summer season. The autumn growth period of temperate grasses enabled further accumulation of body weight. The reduction in herbage availability and quality during winter would explain the gradual, but continual reduction in body weight throughout this season resulting in the lowest body weights being recorded at the end of winter and start of spring. These results show a seasonal affect on energy intake and feeding behaviour, and are supported by those of Kuntz *et al*. (2006) reporting the vDMI and body condition of

Przewalski horses in Austria. Body condition of the horses reached a nadir in April due to poor nutritive quality of winter grazing. As grazing quality increased throughout spring and summer, body weight increased reaching a maximum in October. The increase in body weight throughout summer until autumn, when food availability is greatest, shows the horses were consuming energy in excess of maintenance requirements. The higher nutritional quality of grazing, combined with lower metabolic rates in spring and summer compared to winter, resulted in excess energy being stored as fat. In natural environments it appears this excess weight is utilised during the colder winter months when food availability is reduced. However, in the domestic situation, ample supplies of preserved forages help animals to maintain body weight, often preventing this natural annual rhythm of body weight fluctuation, increasing the susceptibility of further weight gain during the following year.

2.3.2 Animal Factors

Studies into the metabolic rate of donkeys and horses indicate that resting metabolic rates in these two species are similar (Yousef & Dill, 1969; Pearson *et al*., 1998), but that donkeys may have lower energy expenditure when walking compared to horses (Pearson *et al*., 1998). The smaller body weight of donkeys and lower energy requirements for normal daily activity would therefore reduce total daily energy requirements, depending on activity level, of donkeys compared to horses.

Current maintenance DE recommendations for horses include a daily activity and thermoregulation allowance of 29.1% of basal energy requirements (NRC, 1989). The energy cost of walking in donkeys is on average 69% of that of horses (Pearson *et al*., 1998). Therefore it could be proposed that the energy allowance for daily activity in donkeys be reduced to 20% of basal energy requirements.

Foraging Effort

The energy expense of foraging includes the energy cost of searching for food and the energy cost of eating. The further the distance travelled when searching for food the greater the energy expense, although terrain will influence this energy cost. Horses have been reported to travel between 4 and 15km per day (Fraser & Brown, 1997; Asai *et al*., 1999). The distance travelled by donkeys has not been recorded. Asai *et al*. (1999) reported an energy cost of 4.2MJ per hour spent grazing in growing horses. The primary cause of this energy expense is the cost of muscular activity and walking (Osuji, 1974), therefore it is suggested that the energy cost of grazing in donkeys is less than that of horses.

The energy cost of eating is a direct function of time spent eating (Osuji, 1974). Eating energy expense is also influenced by food type. Fibrous preserved forages have a higher eating energy cost (MJ/kg DM consumed) than less fibrous forages and pelleted diets due to the higher chewing effort and longer eating times required for fibrous forages (Mueller *et al*., 1998; Harris, 1999; Smith, 1999). Eating energy cost of consuming fresh pasture has been shown to be higher than that of eating preserved forages in sheep due to the lower DM content and thus increased eating time per unit of DM consumed (Osuji, 1974; Vernet, Vermorel & Martin-Rosset, 1995).

2.3.3 Methods used to Calculate Energy Requirements

Homeothermic animals maintain core body temperature within a narrow range. Sensible (conduction, convection and radiation) and insensible (evaporation) heat losses, and heat gained from food eaten, muscular activity and the environment, are regulated to maintain a stable body temperature (Kaiyala & Ramsay, 2010). The heat generated by a homeothermic animal within its thermoneutral zone, that is not eating and is resting but not sleeping, is equivalent to the amount of energy generated through metabolic processes, and is termed resting metabolism (Blaxter, 1989). The most direct method of measuring resting metabolic rate in animals is direct calorimetry. Direct calorimetry measures the heat generated by the animal (sensible and insensible heat loss) when housed in an insulated, sealed chamber (calorimeter) with a regulated and monitored air supply (McLean & Tobin, 2008). Sensible heat losses are measured by the change in temperature of either a barrier layer (isothermal calorimeter) or a liquid cooled heat exchanger (heat-sink calorimeter) (Kaiyala & Ramsay, 2010). Evaporative losses are measured by changes in temperature and humidity of air within or exiting the chamber, compared to air entering the chamber (McLean & Tobin, 2008).

The use of direct calorimetry in the study of energy metabolism in animals has reduced considerably since the development of indirect methods. Calorimeters are expensive to construct and maintain in comparison to indirect calorimetry methods. The requirement for animals to be restrained or housed within calorimetry chambers limits the measurement of energy metabolism to animals that are relatively easy to handle and that do not become stressed in confined spaces. The need to keep animals relatively immobile and in an unnatural environment also makes direct calorimetry unsuitable for measuring energy metabolism in working animals.

Indirect Calorimetry

Indirect calorimetry measures the heat produced by an animal. As the term 'indirect' implies, the heat produced by the animal is not measured directly. Products containing energy that are produced by the animal are measured, and total heat production is estimated from these measurements. During indirect calorimetry measurements of oxygen (O_2) consumption, carbon dioxide (CO_2) production, and nitrogen (N) excretion (by the measurement of urine and methane (CH_4) production) are made (Battley, 1995). Using the gaseous exchange equation described by Brouwer (1965) (Equation 2.1), the amount of heat produced by the animal can be calculated.

Equation 2.1.

$$\text{Heat production (kJ)} = (16.2 \times O) + (5.1 \times CO) - (5.9 \times U) - (2.4 \times CH_4)$$

Where:

O: O_2 consumption (litre)
CO: CO_2 produced (litre)
U: Urinary nitrogen excreted (g)
CH_4: Methane produced (litre)

Heat production can be estimated from measurement of all components in equation 2.1, or from measurement of specific components only. Through measurement of both O_2 and CO_2, or O_2 or CO_2 alone, heat production can be estimated from the ratio of CO_2 production to O_2 consumption, known as the respiratory quotient (RQ). The RQ varies depending on the nutrients oxidised during metabolism (See Table 2.5). Upon measurement of the amount of O_2 consumed and/or CO_2 produced, estimated heat production can be calculated using the RQ and heat per litre of oxygen (kJ) values stated in Table 2.5.

Table 2.5. The heat equivalent of oxygen and carbon dioxide under different circumstances according to Brouwer (1965) (adapted from Blaxter, 1989)

Substrate Oxidised	Respiratory Quotient	O_2 consumed (kJ/l)	CO_2 produced (kJ/l)
Lipid	0.711	19.7	27.8
Protein	0.809	19.2	23.8
Carbohydrate	1.000	21.2	21.2
Values normally chosen when only one gas determined	-	20.1	24.1

Methods of Indirect Calorimetry used to Measure Energy Requirements in Equids

Energy requirements of horses for maintenance have been measured in respiratory chambers using a combination of digestibility trials and indirect open-circuit calorimetry techniques (Vermorel, Martin-Rosset & Vernet, 1991; Vermorel, Vernet & Martin-Rosset, 1997a; Vermorel, Martin-Rosset & Vernet, 1997b). Digestibility trials measuring food refusals and faecal and urinary output, whilst feeding measured rations, enable calculation of gross energy intake and faecal and urinary energy output from analysis of food offered and faeces and urine for energy and nutrient content. Open-circuit calorimetry methods were used to estimate heat production through measurement of O_2 consumption, CO_2 production and CH_4 excretion. Incoming air to the respiratory chamber was kept at a constant rate and out flowing air sampled. In the studies by Vermorel *et al*. (1991; 1997a and 1997b) O_2, CO_2 and CH_4 air content was measured from samples of air taken continuously and by composite samples taken periodically over 23 hours/day. The equation described by Brouwer (1965) was used to estimate heat production from O_2, CO_2 and CH_4 measurements.

Wooden, Knox & Wild (1970) also used a combination of digestibility trials and an open-circuit system to estimate maintenance energy requirements in 2 horses. However Wooden and colleagues maintained the animals in metabolism rooms and used a face mask to measure gaseous exchange. A leaky face mask, allowing air to pass over the horses face at a constant rate, was used to sample ingoing and outgoing air for concentrations of O_2, CO_2 and CH_4. Wooden and colleagues accounted for methane lost as flatulence from the amount of crude fibre digested and an equation suggested for horses by Lehmann, Hagemann & Zuntz (1894, cited by Wooden *et al*., 1970) (CH_4 lost via flatulence (g) = 4.73 x 100g crude fibre digested). Net energy retention was calculated by deducting energy lost via faeces, urine, CH_4 and total heat production (Wooden *et al*., 1970). Pagan & Hintz (1986) used the same method as Wooden *et al*. (1970) except for methane measurements. Pagan & Hintz (1986) estimated methane production from caecal volatile fatty acid (VFA) ratios according to Wolin (1960), calculated from caecally fistulated ponies fed the same experimental diet.

Open-circuit systems have also been used to estimate energy metabolism in donkeys. Yousef & Dill (1969) estimated the energy metabolism of 2 donkeys whilst standing using a gastight mask. The volume of expired air was measured and then passed through a neoprene meteorological balloon. As the expired air left the bag samples were collected and analysed for O_2 and CO_2. Pearson *et al*. (1998) used a portable breath by breath system (Mach I Oxylog) that measured O_2 consumption to calculate the energy requirements of 4 donkeys when standing, walking unloaded and walking carrying loads. The Oxylog system used an airtight mask and measured the flow of ingoing air. After each breath samples of air entering and leaving the mask were taken and passed into separate reservoirs containing a solid desiccant. A running average of O_2 concentrations in the sample air is given and total O_2 consumption calculated (Pearson *et al.*, 1998). Energy consumption was calculated from gaseous exchange, assuming 20.7kJ of energy consumed per litre of O_2 consumed, according to Brouwer (1965).

Further measurements of energy losses in donkeys, via direct or indirect calorimetry methods, would provide more information on the digestive efficiency of the donkey, and enable energy losses by donkeys to be compared to those by horses. Such information would help to determine if systems for calculating energy requirements in horses are suitable for calculating energy requirements in donkeys.

An alternative to using calorimetry methods measuring O_2 consumption and CO_2 production, is the use of doubly labelled water to calculate CO_2 production, and thus estimate heat production. Lifson, Gordon & McClintock (1955) measured turnover in the body of water and CO_2 by monitoring the concentration of ^{18}O and deuterium isotopes in the urine of mice, after injection of doubly labelled water ($^2H_2{}^{18}O$). The technique works on the basis that O_2 is eliminated from the body as CO_2 and water, and that hydrogen is eliminated in water only. Oxygen will therefore have a faster turnover rate within the body than hydrogen, with the difference in turnover rates between O_2 and hydrogen providing a measure of the rate of CO_2 production (Lawrence, Pearson and Dijkman, 1991). The animal is dosed with the isotope labelled water and samples taken of either urine or saliva at intervals. Concentrations of isotopes in the urine or saliva are first measured from initial samples taken 0 – 6 hours after dosing to determine the initial isotope concentrations and total body water. Further samples are taken at intervals until the isotope concentrations have fallen to 25 - 12.5% of their original values. From the rate of CO_2 production and the time elapsed since the first dose, the total amount of CO_2 produced can be calculated (Lawrence *et al*., 1991).

The main advantages of the doubly labelled water technique are that animals can continue normal behaviour and follow normal management routines, making results more applicable to how animals are actually managed. Energy expenditure can also be measured over longer periods of time compared to other direct and indirect calorimetry methods (Lawrence *et al*., 1991). However, inaccuracies in the doubly labelled water technique can lead to incorrect measurements of energy expenditure. Losses of hydrogen via methane production, and water via respiration and perspiration, lead to incorrect calculation of CO_2 production. Midwood *et al*. (1989) offer a correction factor for hydrogen loss via methane derived from a study in sheep, based on the ratio of methane to body fluid. Fuller *et al*. (2004) used this correction equation to account for hydrogen lost in methane by ponies in a study comparing doubly labelled water and indirect calorimetry. A solution to loss of water via respiration and perspiration has been developed by introduction of a third isotope into the water (Haggarty, McGaw & Franklin, 1988). Water labelled with either ^{17}O or ^{3}H in addition to $^{2}H_2{}^{18}O$ is infused into the animal as previously described. The different isotopes separate to different extents between the liquid and vapour phases during the evaporation of water (Lawrence *et al*., 1991), allowing the rate of loss of water by evaporation to be calculated. A review of literature did not find any studies using triple labelled water to estimate energy metabolism in equids.

The simplest and most straight forward method that has been used to calculate maintenance energy requirements in equines is the use of body weight as the indicator that maintenance energy requirements are met. Stillions & Nelson (1972) used zero change in body weight and intake measurements to determine DE requirements for maintenance in 6 horses. Rations were adjusted to maintain a constant body weight for 30 days followed by 6 days faecal collection. However, due to changes in gut volume, defecation and urination, body weight fluctuates throughout a 24 hour period. In sheep fed *ad libitum* body weight was reported to increase 22% above that recorded during fasting (Blaxter, 1989), with changes in gut volume being greater in herbivores compared to non-herbivores.

Frequent measurement of body weight over long study periods provides a more representative view of body weight changes. However, the use of body weight to calculate quantities of food required to maintain body weight, can lead to a circular effect. Losses in body weight lead to a reduction in food offered due to rations being calculated on a body weight basis, leading to continued loss of body weight. Animal keepers aiming to maintain their animals at a constant body weight must use their husbandry skills to adjust rations to maintain body weight.

2.3.4. Current Maintenance Energy Recommendations for Horses

Digestible Energy System

The formulation of feeding recommendations for any animal requires knowledge of both the animal's nutrient requirements and the nutrient content of the food to be fed. The simplest system providing recommendations for energy requirements, and the system used in horse feeding recommendations in America and the UK, is the DE system. Calculation of an animal's DEI is relatively simple from the difference between gross energy intake and faecal energy output (Blaxter, 1989). Digestibility trials are used to calculate these fractions, requiring animals to be individually housed and DMI and faecal DM output to be measured. Using bomb calorimetry, food and faecal gross energy values are measured and DEI calculated. The DE value of the food offered is calculated from the gross energy value of the food and DM digestibility. The DE value of foods can also be estimated from the value of other nutrient factors (ADF, CP) using equations provided by NRC (1989) horse feeding recommendations. More recently *in vitro* gas production has been used to estimate the DE value of foods for horses (Lowman *et al*., 1999). Horse feeding recommendations produced by the National Research Council have historically used the DE system, and continue to do so in the newly revised 6th edition of feeding recommendations for horses (NRC, 2007). The feeding recommendations published by the NRC are compiled from published studies of equine nutrition. The most recent edition of the NRC recommendations (NRC, 2007) uses results from five studies using between 2 and 8 animals per study (body weight range 125 – 856kg), to formulate maintenance DE recommendations (Wooden *et al*., 1970; Pagan & Hintz, 1986; Vermorel *et al*., 1991; Vermorel *et al*., 1997a,b). In all of the five studies used to formulate maintenance energy recommendations, the animals were enclosed in either respiratory chambers or metabolism rooms, limiting daily activity and reducing the amount of energy expended. To account for daily activity of equids managed under normal conditions (field access, free movement within stable, regular handling), three levels (minimum, average, elevated) of maintenance energy requirements are included in the 2007 NRC recommendations. The lowest (minimum level) maintenance DE required (126.8kJ/kg BW/day) is that derived from the 5 previously discussed studies, and is recommended for very docile horses or those with restricted movement. To allow for increased daily voluntary activity levels in the average horse (average level) maintenance DE recommendations increase by 10% to 139.3kJ/kg BW/day. This increase was included to account for activity during daily field turn out and for a more alert temperament. The highest (elevated) maintenance DE recommendation is 151.9kJ/kg BW/day. The higher level was formulated for horses that have a more nervous temperament such as stallions and young horses, and for those horses more active when in the field or stable (NRC, 2007). The provision of three levels of maintenance DE requirements is an improvement on the 5th edition of the recommendations (NRC, 1989) as it enables those formulating rations to account, with greater accuracy, for individual animal characteristics and temperaments. Lawrence (2007) suggested using the minimum level of maintenance DE requirement for ponies and horses that maintain body condition easily (easy keepers), and the elevated level of DE requirement for horses that find it difficult to keep body condition (hard keepers).

Limitations of the DE system are that no account can be made for the amount of energy available to the animal. The DE system does not account for energy lost via urine, methane, eating energy cost and heat increment. The higher heat increment and eating energy cost of fibrous forages compared to less fibrous feeds results in energy available to the animal being overestimated for fibrous foods when using the DE system (Cuddeford, 2000; NRC, 2007). However, the availability of DE values for many foods that are fed to horses, combined with the relatively easy equations used to calculate energy requirements, make the DE system accessible to people with varying levels of equine nutrition knowledge.

Net Energy System

The French Net Energy (NE) system has been developed to address the limitations of the DE system highlighted above. The NE system is the official feeding standard system in France and is in use in western, and some eastern, European countries (Martin-Rosset, 2001). The NE system uses measurements of ME and DE derived from feeding trials and studies using indirect calorimetry (Wooden *et al*., 1070; Stillions & Nelson, 1972; Anderson *et al*., 1983). From these studies recommendations for the amount of NE required by horses were formulated. Calculation of the amount of food needed to satisfy an animals NE requirements is then calculated from the amount of energy provided by the food on offer. The NE system uses horse feed units (UFC) as the measure of a foods energy value. A foods UFC value is calculated against the energy provided by a reference feed (standard barley of 87% DM). One UFC unit corresponds to the NE value of 1kg of standard barley in a horse at maintenance (2250kcals/9414kJ) (Martin-Rosset *et al*., 1994). The UFC value of a feed is calculated by dividing its NE content (kcals) by that of standard barley (2250kcals), producing a UFC/kg DM value (Martin-Rosset *et al*., 1994). The UFC value of a feed can be calculated either directly from equations using other nutrient factors (crude fibre (CF), CP, DE, digestible organic matter (DOM), cytoplasmic carbohydrates (CC), or from estimation of the NE value first, followed by calculation of the UFC value as stated above (see Appendix 1 for calculations). Compilation of UFC values for foods commonly fed to horses (INRA, 1990) has reduced the number of calculations needed to formulate rations. However, the use of energy value tables, whether expressing DE, NE or UFC values, reduces the accuracy with which formulated rations meet energy requirements.

2.3.5 Maintenance Digestible Energy Requirements of Mature Donkeys

To date seven studies have reported DEI by donkeys (Table 2.6). Of these studies, four reported energy intakes in excess of energy requirements, evident by increases in body weight. Digestible energy intakes (MJ/kg $BW^{0.75}$) of donkeys gaining weight ranged from 0.44 when receiving an oat straw diet (Cuddeford *et al*., 1995) to 1.05 when receiving a diet of alfalfa hay (Pearson *et al*., 2001).

However, the increase in body weight by the donkeys in the study by Cuddeford *et al*. (1995) was attributed to greater gut fill and not to an increase in body mass. Maintenance of body weight by donkeys receiving hay and straw diets was reported in three studies (Izraely *et al*., 1989b; Mueller *et al*., 1994; Pearson *et al*., 2001). Digestible energy intakes per kilogram of metabolic body weight for donkeys in these studies ranged from 0.48 MJ when consuming a diet of oat straw (Pearson *et al*., 2001) to 1.13 MJ when offered alfalfa hay *ad libitum* (Izraely *et al*., 1989b), although once again maintenance of body weight on the straw diet was thought to be due to gut fill. Using only results from the studies by Izraely *et al*. (1989b) and Mueller *et al*. (1994), maintenance DE requirements by donkeys appear to range from 0.53 to 1.13 MJ/kg $BW^{0.75}$. The lower DEI by the donkeys in the study by Mueller *et al*. (1994), however, may not be representative of maintenance energy requirements as DEI are within the range of energy intakes (0.29 – 0.62 MJ/kg $BW^{0.75}$) leading to losses in body weight (Table 2.6). The short (4 weeks) recording period of donkeys receiving the hay diets in the study by Mueller *et al*. (1994) was probably insufficient for any energy deficits to become apparent.

Table 2.6. Mean digestible energy intakes (DEI MJ/kg BW$^{0.75}$) by donkeys fed different forage based diets

No. of animals	BW (kg)	Diet	Feeding Level	DEI (MJ/kg BW$^{0.75}$)	Reference
5	129	Alfalfa hay	*Ad libitum*	1.13	Izraely *et al*. 1989b
	117	Wheat straw	*Ad libitum*	0.56	
4	179	Meadow hay	*Ad libitum*	0.87	Pearson & Merritt, 1991
		Barley straw	*Ad libitum*	0.29	
5	198	Grass hay (poor quality)	*Ad libitum*	0.53	Mueller *et al*. 1994
		Grass/legume hay	*Ad libitum*	0.64	
4	174	Alfalfa hay: oat straw (100: 0)	M	0.47	Cuddeford *et al*. 1995
		Alfalfa hay: oat straw (67: 33)	M	0.47	
		Alfalfa hay: oat straw (67: 33)	M	0.51	
		Alfalfa hay: oat straw (0: 100)	M	0.44	
4	155	Hay (poor quality)	*Ad libitum*	0.53	Nengomasha *et al*. 1999
4	197	Molassed alfalfa hay	*Ad libitum*	1.05	Pearson *et al*. 2001
	182	Molassed oat straw	*Ad libitum*	0.48	
6	142	Sorghum fodder plus Concentrate	*Ad libitum* 1kg	0.90	Ram *et al*. 2004

M: Fed to calculated maintenance energy requirements of horses (NRC, 1989)

Combining the results from all studies reporting DEI by donkeys and accounting for changes in body weight, it is proposed that maintenance DE requirements of donkeys ranges between 0.62MJ per kg $BW^{0.75}$ (highest DEI at which donkeys lost weight) and 0.88MJ per kg $BW^{0.75}$ (lowest DEI at which donkeys gained weight) however further research is necessary to calculate the maintenance DE requirements of donkeys in the UK over a prolonged time period. Calculation of the effect of season on energy requirements is also necessary to prevent donkeys gaining excess weight in the spring and summer seasons.

Comparison of DEI by donkeys with current maintenance energy recommendations for horses (NRC, 2007) is difficult as donkeys are generally of lower body weight than the range suitable for current prediction equations (200kg plus). However, studies using donkeys and ponies can be used to compare voluntary DEI by the two species (Pearson & Merritt, 1991; Pearson *et al*., 2001). On average donkeys consumed 20% less DE (MJ/kg $BW^{0.75}$) but digested GE more efficiently than the ponies. The higher GE digestibilities did not compensate fully for the lower vDMI reported for donkeys in the studies by Pearson & Merritt (1991) and Pearson *et al*. (2001), indicating that on a metabolic body weight basis the DE requirements of donkeys are lower than those of ponies.

2.3.6 Current Maintenance Digestible Energy Recommendations for Donkeys

In an attempt to estimate nutrient and energy requirements of donkeys McCarthy (1989) and Taylor (2000) proposed feeding on a body weight basis 0.75 of calculated horse requirements to account for the greater digestive efficiency of the donkey compared to the horse. However, it is not known if these recommendations also overestimate donkey energy requirements, increasing the likelihood of donkeys becoming overweight. Calculation of maintenance energy requirements of donkeys is the first step in establishing feeding guidelines for donkeys, and is imperative in preventing malnutrition or obesity in donkeys.

2.3.7 Summary of Digestible Energy Requirements of Donkeys

Calculation of maintenance energy requirements will enable feeding regimes aimed to increase or reduce body weight to be calculated more accurately. Studies comparing the energy cost of standing and walking indicate that donkeys have similar metabolic rates to horses but that they are more energy efficient at walking. Combined with the lower body weight of the donkey, these results suggest that the maintenance requirements of donkeys are lower than those of horses. Results comparing DEI by donkeys and ponies support this theory although actual maintenance requirements of donkeys have not been accurately determined. Calculation of the energy required to maintain body weight over a prolonged time period is necessary. Assessing energy requirements during different seasons will also enable the affect of different climatic conditions on energy demands to be calculated; to date these factors have not been investigated in donkeys. Calculating the donkeys' maintenance energy requirements will enable donkey specific feeding guidelines to be compiled. However, these guidelines must be of practical use to owners and hence must take into account the management systems and feeds owners have available to them. At present there is little information available on how donkeys are managed and fed in the UK. The Professional Handbook of the Donkey (2000) provides advice on how to manage donkeys, however it is not known if this advice is followed by donkey owners. It is therefore essential that this information be sought prior to the formulation of feeding guidelines.

CHAPTER 3
A SURVEY OF THE HUSBANDRY PRACTICES OF DONKEYS IN THE UK

3.1 INTRODUCTION

It was proposed in Chapter 1 that obesity is common in the UK donkey population. The first step in improving the welfare of donkeys in the UK would be to quantify the scale of the problem. Second would be identification of factors leading to excess weight gain in donkeys. The formulation of donkey specific feeding guidelines should enable owners to estimate their donkeys feeding requirements more precisely, and adjust their donkeys' diet in response to changes in their nutritional status. To date there have been few studies of how donkeys are managed in developed countries. Miraglia, Polidori & Salimei (2003) describe the keeping of donkeys, mules and horses for riding purposes and meat and milk production in Central-Southern Italy, where the equids are managed extensively without the feeding of supplementary food and using a natural mating system. The Professional Handbook of the Donkey (2000) includes chapters on donkey husbandry, providing advice for owners on how to care for their donkey. However there have been no studies into how owners manage their donkeys in the UK. Results from the few studies into how horses in developed countries are managed have focused on husbandry practices of riding horses (Honoré & Uhlinger, 1994; Mellor *et al.*, 1999; Mellor *et al.*, 2001; Hotchkiss, Reid & Christley, 2007), and young growing horses (Gibbs & Cohen, 2001), therefore results are likely to be inapplicable to how donkeys are kept.

A postal survey gathered information on donkey health and body condition and on the husbandry and feeding practices used to manage donkeys in the UK during each season (section 3.2.3 Compiled Questionnaire and Appendix 2).

3.1.1 Survey Aims

The survey was targeted at private donkey owners and Donkey Sanctuary foster owners distributed throughout the UK, Channel Islands and the Republic of Ireland. Aims of the survey were:

1. To determine the prevalence of obesity in the UK donkey population
2. To determine the common husbandry practices used to manage donkeys in the UK
3. To identify the types of foods fed to donkeys during each UK season
4. To assess the level of owner knowledge about donkey nutritional requirements

Research Objectives

- To identify husbandry factors influencing the feeding practices of donkey owners and, using these factors, design a postal questionnaire to gather information on how donkeys in the UK are managed and fed during each season
- Recruit donkey owners to participate in the survey via Donkey Sanctuary Welfare Officers and adverts in equestrian publications
- Distribute questionnaires to survey participants every 3 months for the duration of 1 year
- Collate and statistically analyse data on a monthly and seasonal basis

3.2 MATERIALS AND METHODS

3.2.1 Experimental Design

A postal survey was undertaken from September 1st 2004 until August 31st 2005. The year was split into 4 seasons with each season comprising 3 months; autumn (September to November), winter (December to February), spring (March to May) and summer (June to August). For each season participants received one questionnaire. Each questionnaire recorded information for 3 months, reducing postal costs and participant workload. The survey was coordinated from the Centre for Tropical Veterinary Medicine (CTVM) at Edinburgh University with all surveys distributed from and returned to this location.

3.2.2 Survey Design

The aim of the survey was to gather information about donkey management, feeding practices, health, body weight, and body condition in the UK. Husbandry factors, types of foods fed and quantities of food fed were identified as influences on the nutritional intake of donkeys through group discussion with the research team (Dr Faith Burden, Dr David Smith, Catherine Muir) (Table 3.1). Using the factors identified in Table 3.1, a questionnaire was compiled (section 3.2.3 Compiled Questionnaire and Appendix 2). The questionnaire was split into three sections focusing on management details, feeding regime and donkey requirements. Where possible, information was gained using closed questions, requiring a tick in an appropriate box. Closed questions were either ‘yes’ or ‘no’ questions, or multiple choice questions where answer options were compiled from methods of equine management commonly practiced. Every question was given an additional option for participants to give more detailed information. Where question responses were expected to be numeric, tables were provided to give strong direction to participants about what information was requested.

Table 3.1. Factors influencing feeding practices of donkey owners

Factor	Trait	Rational
Management Routine	Use of premises where donkeys are kept (e.g. commercial equine yard, private land, commercial farm)	May affect the resources available to owners and ease with which owners can adjust their donkeys' management routine
	Number and species of field and stable companions	Influences the amount of competition for food and grazing and may affect how donkeys are managed
	Number of hours donkeys are restricted to a stable and/or yarded* area, and the number of hours they have access to pasture per day	The number of hours at grass will influence total DM and DE intake and the amount of supplementary dried forages and concentrates fed
	Provision of field shelter/natural protection (hedges or trees) from weather conditions	Influences the energy requirement to maintain body temperature in cold, wet, windy conditions
	Bedding type used	The use of edible bedding affects the ability of owners to regulate their donkeys' forage intake
Pasture Access and Management	Size of donkeys' grazing area Method used to restrict donkeys' grazing access (e.g. strip grazing, time restriction)	Influences pasture intake and supplementary feeding level. Method of grazing restriction may also affect grazing behaviour
	Condition of grazing area	Affects the nutrients available in the pasture and the number of animals able to graze in a specific area
	Number and species of trees and shrubs within or adjacent to grazing area	May increase the donkey's intake from browse
	Number and species of poisonous plants within grazing area	Affects pasture value
	Methods used to manage grazing area (e.g. removing droppings, resting, fertilising, rolling, topping) Frequency of these management practices	Influences pasture condition, nutrient content and parasitic burden of grazing pasture

* Free to access shelter if required but no access to pasture

Table 3.1. Continued.

Factor	Trait	Rational
Donkey Requirements	Donkeys age	Affects nutrient requirements. Growing and elderly donkeys may have different requirements than mature donkeys
	Donkeys body condition	Influences the donkey's energy requirement and the aim of the feeding regime
	Duration and intensity of the donkeys exercise programme	Affects daily energy requirements and feeding routine
	Previous and current health problems experienced by the donkey	May prevent/require the feeding of specific foodstuffs
Feeding Practices	Types of food fed	Influences eating time, vDMI and energy density of ration
	Availability of different food types and commercial feeds	Influences the type and brand of food owners choose to feed to their donkeys
	Method of feeding	May affect the ease with which food can be consumed
	Supplements fed	Influences specific nutrient intakes

3.2.3 Compiled Questionnaire

The following questions compiled the questionnaire.

1. Management Details

1.1 Please indicate the number of hours per day your donkey spends stabled, at grass or yarded.

(Table used to gain information on the average number of hours donkeys spent each day stabled, yarded or at grass each month).

1.2 When stabled, what type of bedding is provided?

1.3 Does your donkey eat bedding material?

1.4 When at grass, does your donkey have field companions?

If so, please indicate species and number.

Donkeys Horses/Ponies Cattle Sheep Pigs Mules

Other

1.5 When at grass, what is the total amount of grazing available per donkey per day?

 # Delete as appropriate ____________ Acres/Hectare #

1.6 Do you manage/restrict the amount of grazing available to your donkey, if so by what means?

(Table used to determine if owners restricted their donkeys grazing by strip grazing, limiting the grazing area or by time)

1.7 Indicate any methods used to manage pasture and the frequency carried out.

(Table used to determine if owners grazed other livestock on their donkeys grazing pasture, and how frequently owners removed droppings, fertilized, rested, rolled or topped their donkeys pasture each month.

1.8 Please indicate if any of the following are present in your pasture.

Ragwort	Clover	Foxglove	Bracken	Horsetails
Nettles	Deadly Nightshade		Docks	Buttercup

1.9 Please indicate if any of the following trees border your pasture.

Yew	Laburnum		Oak	Box

1.10 Indicate the percentage of the following present within your donkey's allocated daily grazing during each month.

(Table used to determine if clover, moss and weeds were present in the donkeys pasture and if the pasture was poached or water logged. Owners were asked to assess the degree of coverage within the donkeys pasture (none of the pasture, or ¼, ½, ¾ or all of the pasture)

2. Feeding Regime

2.1 Please list the different feeds given to your donkey during the past three months.

(Table used to gain information on the type of food fed (forage/concentrate), the source of the food (home grown/locally produced/commercially produced) and the brand or company producing the food.

2.2 Indicate the type and quantity of food fed and the frequency of feeding for each recording period.

(Table used to gain information on the total amount of each food type fed per day, and the number of meals each donkey received each day, on a monthly basis)

3. Donkey Requirements

3.1 Please record your donkey's measurements and condition score using the guidelines provided.

(Table used to record measurements of the donkeys heart girth, height, length and body condition score each month)

3.2 Indicate if you were planning for your donkey to maintain, lose or gain weight during months 1,2 and 3. Please also indicate what work (if any) your donkey did during months 1 – 3.

Feeding to	Maintain BW	Lose BW	Gain BW
Work done (hrs/week)	Ridden	Driven	In-hand

Please use the space below to provide any further information you feel may be of relevance.

An additional question sheet was provided with the first and last seasons' questionnaires. The first season's questionnaire included questions on owner details, donkey details, donkey health and premises details. The final season's questionnaire asked for information on areas where owners experience difficulty in caring for their donkeys and any areas where owners feel information is lacking. Participants were also asked to provide feedback on the questionnaire and survey.

3.2.4 Participant Recruitment

Published information on management practices used by donkey owners in the UK is lacking. To maximise the number of participants recruited, and the diversity of the sample population, survey participants were recruited from different sources. Between April and July 2004 requests for participants were placed in popular equestrian publications (Your Horse and Horse & Hound magazines), and newsletters from the Mule Society and the Donkey Breed Society (Bray Talk). Recruitment letters were also distributed through the Donkey Sanctuary Welfare Officers to approximately 800 Donkey Sanctuary foster homes. The use of both Donkey Sanctuary foster homes and independent owners provided information from owners of different backgrounds, circumstances, and with different resources. Interested owners were asked to register their interest either via post or by email. August 1st 2004 was the cut off date for participant recruitment, allowing compilation of a participant mailing list and starter packs to be distributed prior to the start of the survey.

In situations where more than one donkey was owned by a participant, one donkey was selected as the focus animal for the duration of the survey. Each participant returned one questionnaire per donkey per season. A total of 178 owners were recruited as survey participants.

3.2.5 Quantitative Measurements

Donkey Biometric Measurements

Information on donkey height, length, heart girth and body condition score were collected on a monthly basis by survey participants. Donkey heart girth and length were to be used to estimate body weight using the two measurement (girth and length) equation described by Pearson and Ouassat (2000). However, body length measurements were not provided by all participants. To remove any variation in the estimated body weight of the donkeys, the one measurement equation (Equation 3.1) described by Pearson and Ouassat (2000), using heart girth only, was used.

Equation 3.1

$$BW\ (kg) = \frac{\text{heart girth (cm)} \times 2.65}{2188}$$

All measurements were made by participants with a tape measure provided at the start of the survey. Participants were directed to measure their donkeys as shown to them in Figure 3.1 on the same day each month. A body condition score chart, compiled by The Donkey Sanctuary (The Donkey Sanctuary, Devon, UK), was provided to aid participants in condition scoring their donkeys (Figure 3.2).

Figure 3.1. Measurements taken by participant owners to determine donkey height, length and heart girth

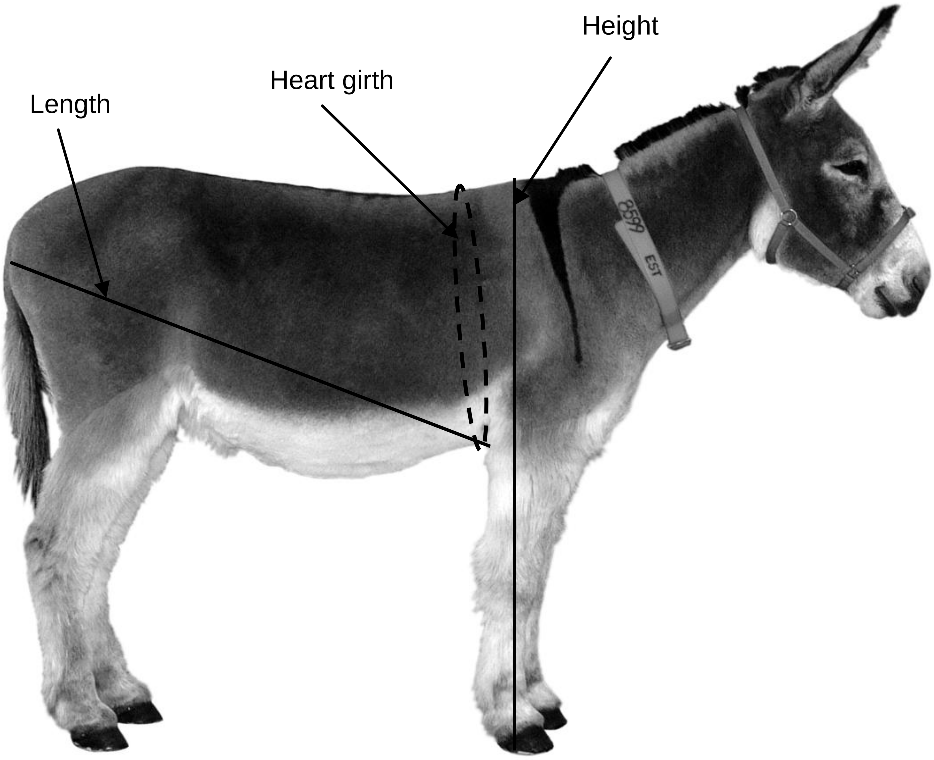


Figure 3.2. Body condition score chart for donkeys in the UK, enabling assessment of body condition score of donkeys in the UK (The Donkey Sanctuary, 2005). Provided to survey participants as a double sided A4 laminated poster.

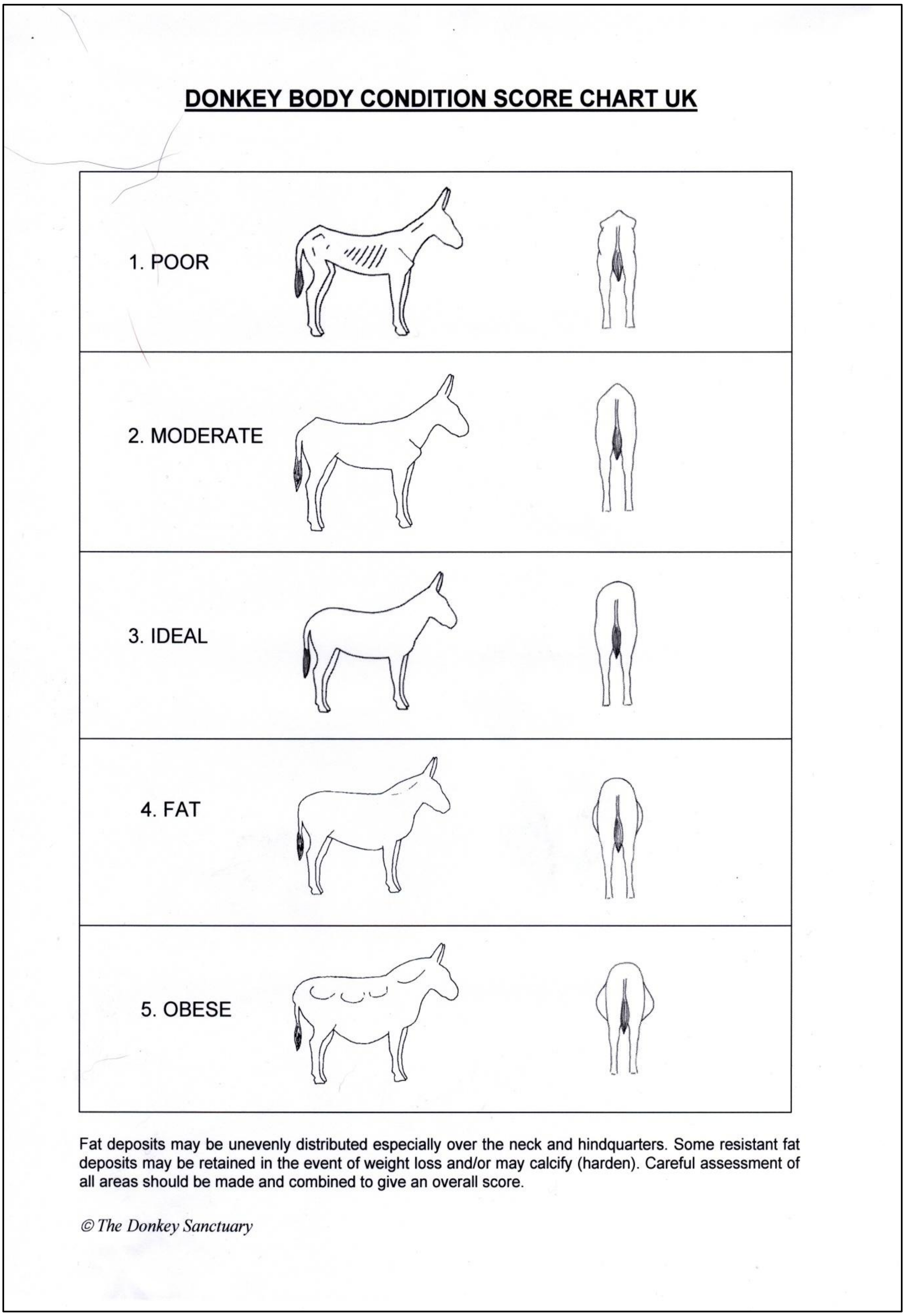


Figure 3.2. Continued.

C/S	NECK AND SHOULDERS	WITHERS	RIBS AND BELLY	BACK AND LOINS	HINDQUARTERS
1. POOR	Neck thin, all bones easily felt. Neck meets shoulder abruptly, shoulder bones felt easily, angular.	Dorsal spine of withers prominent and easily felt.	Ribs can be seen from a distance and felt with ease. Belly tucked up.	Backbone prominent, can feel dorsal and transverse processes easily.	Hip bones visible and felt easily (hock and pin bones). Little muscle cover. May be cavity under tail.
2. MODERATE	Some muscle development overlying bones. Slight step where neck meets shoulders.	Some cover over dorsal withers, spinous processes felt but not prominent.	Ribs not visible but can be felt with ease.	Dorsal and transverse processes felt with light pressure. Poor muscle development either side midline.	Poor muscle cover on hindquarters, hipbones felt with ease.
3. IDEAL	Good muscle development, bones felt under light cover of muscle/fat. Neck flows smoothly into shoulder, which is rounded.	Good cover of muscle/fat over dorsal spinous processes withers flow smoothly into back.	Ribs just covered by light layer of fat/muscle, ribs can be felt with light pressure. Belly firm with good muscle tone and flattish outline.	Cannot feel individual spinous or transverse processes. Muscle development either side of midline is good.	Good muscle cover in hindquarters, hipbones rounded in appearance, can be felt with light pressure.
4. FAT	Neck thick, crest hard, shoulder covered in even fat layer.	Withers broad, bones felt with firm pressure.	Ribs dorsally only felt with firm pressure, ventral ribs may be felt more easily. Belly overdeveloped.	Can only feel dorsal and transverse processes with firm pressure. Slight crease along midline.	Hindquarters rounded, bones felt only with firm pressure. Fat deposits evenly placed.
5. OBESE	Neck thick, crest bulging with fat and may fall to one side. Shoulder rounded and bulging with fat.	Withers broad, unable to feel bones.	Large, often uneven fat deposits covering dorsal and possibly ventral aspect of ribs. Ribs not palpable. Belly pendulous in depth and width.	Back broad, unable to feel spinous or transverse processes. Deep crease along midline bulging fat either side.	Cannot feel hipbones, fat may overhang either side of tail head, fat often uneven and bulging.

Half scores can be assigned where donkeys fall between scores. Aged donkeys can be hard to condition score due to lack of muscle bulk and tone giving thin appearance dorsally with dropped belly ventrally, while overall condition may be reasonable.

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Food Samples

Participants were asked to take samples of foods offered to their donkeys. Participants were asked to take samples of feeds and pasture grazed in the final week of each season only in order to reduce the chance of samples spoiling. Participants were provided with advice for drying pasture samples. When this was not possible samples were returned to CTVM for immediate freezing.

Equipment

In the month preceding the start of the survey all participants received a starter pack and the first season's questionnaire. The starter pack contained all equipment required and guidelines (Appendix 3) for completing the questionnaire and all practical activities. Equipment was retained for the duration of the survey.

Equipment provided;

- 30 x 30cm metal quadrat
- Large scissors for grass sampling
- Tape measure
- Permanent marker pen for labelling
- Laminated body condition score chart
- Completion guidelines

Sampling Instructions

Participants were instructed to take grab samples of forages fed. For each forage offered, two grab samples were to be taken from the centre of the bale being fed on the day of sampling. Samples were pooled and bagged in an airtight plastic bag and labelled with participant reference number, type of forage and date of sampling. Hay and straw samples were dry enough not to spoil and did not require drying prior to return posting. Participants providing haylage samples were advised to dry samples using the instructions provided.

Pasture samples were taken using a 30 x 30cm metal quadrat thrown at two random places within the donkey's grazing area on the day of sampling. If using strip grazing to manage grazing access, two pasture samples were taken of the ungrazed pasture to be offered to the donkey on the day of sampling. Participants were directed to take pasture samples by holding the grass stems vertically and by cutting stems approximately 2cm above soil level. This helped to prevent soil contamination of pasture samples. Cut grass was then placed into a clean collection bucket and the second pasture sample collected in the same way. Once both samples were gathered the contents of the bucket were gently mixed together and a subsample taken. A subsample consisted of approximately 5 handfuls of cut grass, if available. The subsample was dried on the day of collection.

Drying of grass and haylage samples required subsamples to be cut into 2 - 3cm lengths and placed into an oven/microwave proof dish. Drying times for conventional and microwave ovens were provided in the guidelines (Appendix 3). All dry samples were placed into individual labelled air tight bags and retuned with questionnaires.

Concentrate feeds offered were also sampled. For each concentrate feed, two grab samples were taken, avoiding the food at the very top of the bag, and placed in labelled, airtight bags. Brand and product information were also requested on bag labels. Due to the drying of concentrate feeds in the manufacturing process, drying prior to posting was not necessary. Samples of concentrate feeds offered were only gathered for the first season due to the unexpected high number of participants offering concentrate feeds (32%), and thus high number of samples gained. It was felt the time and resources required to analyse the 37 different products fed would not provide any further information than that which could be gained from the feed manufacturers. Therefore participants were advised not to send any further concentrate feed samples after season 1.

Food Sample Analysis

Participants were divided into 12 geographic regions and 5 participants from each region selected at random for food sample analysis. In regions with less than 5 participants, samples from all participants were used. The same participants were used throughout the survey to determine seasonal variation in nutritional quality.

Prior to analysis, chosen samples were thoroughly defrosted, dried in a force draft oven at 60^{o}C to a constant weight to determine DM, and ground using a hammer mill through a 1mm screen. Samples were analysed for their CP and NDF content according to the methods reported by the Association of Official Analytic Chemists (1990). *In vitro* digestibility was analysed using the neutral cellulase plus gamanase (NCGD) technique developed by Ankom Technology (Ankom, 2006). The NCGD analysis used cellulase and gamanase in an acetate buffer solution to hydrolyse cellulose and galactomannans of NDF residues over a 40 hour period to determine dry matter digestibility. Digestible energy of samples was estimated using equation 3.2 (MAFF, 1987).

Equation 3.2.

$$\text{DE (MJ/kg DM)} = \frac{0.23 + 0.138 \times \text{IVD} + 0.01 \times \text{CP}}{0.81}$$

Where:
IVD: *In vitro* DM digestibility (%)

3.2.6 Data and Statistical Analysis

The sample population for each month comprised of all completed questionnaires for that month, regardless of if data for that donkey was provided for the previous month. This maximised the amount of data gathered each month and meant that participants unable to provide information for every month (due to change in personal circumstance) were able to continue on the survey. Information on management methods was collated on a monthly basis enabling management trends to be identified.

Data was checked for normality of distribution and similarity of variance between treatments using the Anderson-Darling and Levene tests, respectively. Where data were normally distributed the mean and standard error were calculated. Where data were not normally distributed the median and interquartile ranges were reported. Data reported in categories (geldings and females) were assessed for normal distribution using Chi-squared goodness of fit test.

Data gained on condition score, body weight and pasture access time were not normally distributed requiring none parametric tests to be used. Tests of association used Spearman's rank correlation (r_s) and differences between treatment groups (housing system, month, season) were tested using the Kruskal-Wallis test. All statistical analysis was carried out using Minitab 15 (Minitab Ltd, Coventry, UK).

3.3 RESULTS

3.3.1 Response Rate

Prior to distributing the first questionnaire, 3 participants withdrew from the survey leaving a sample population of 175 participants. Fourteen participants were private donkey owners. All of the remaining 161 participants were keeping donkeys under the Donkey Sanctuary foster scheme. Of the 175 participants, 108, 97, 89 and 84 participants completed the questionnaires for autumn, winter, spring and summer, respectively. The success rate for collecting a full data set (12 months) was 48%. Reasons for non-return of questionnaires per season are shown in Table 3.2.

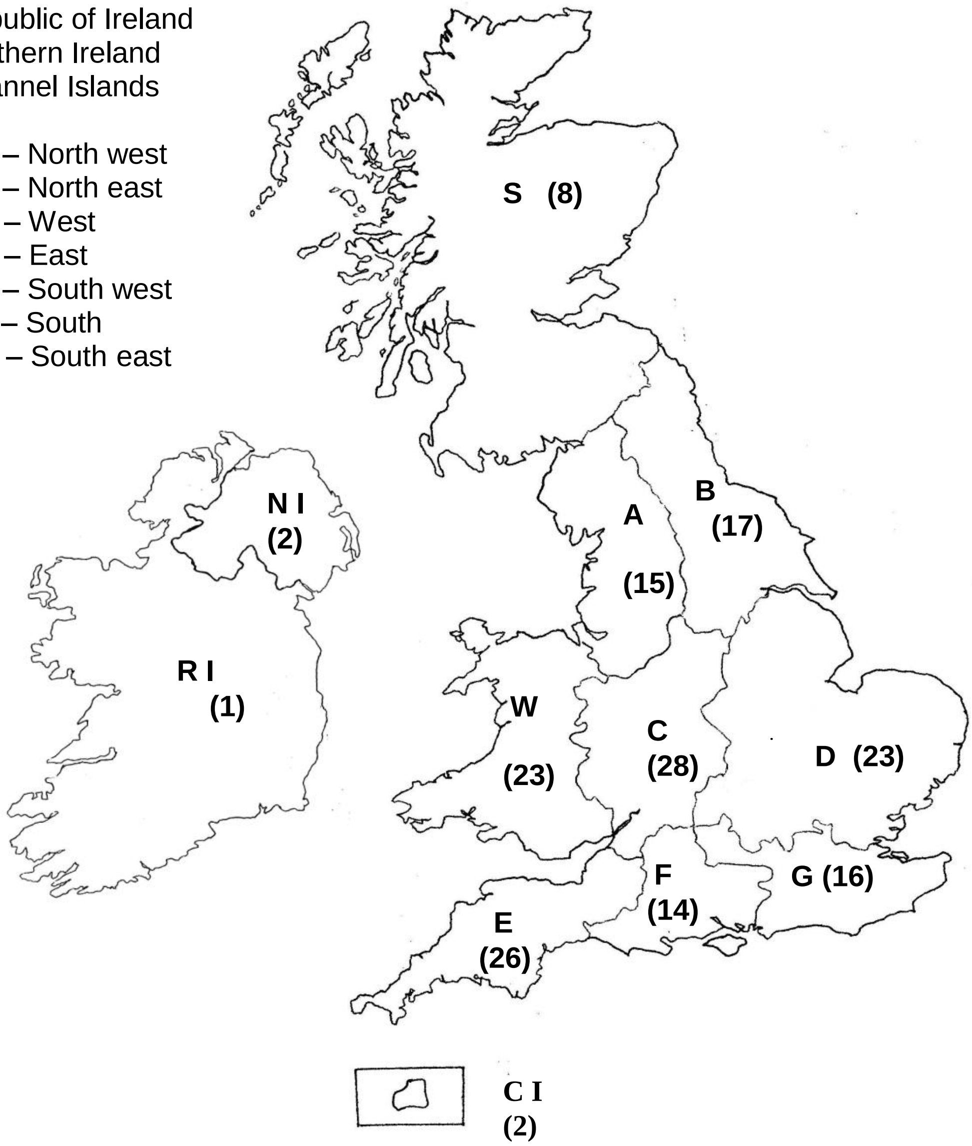
Table 3.2. Number of participants (ex 175) failing to return completed questionnaires each season and the reasons given for non returns

Reason for non-return of questionnaire	Season				Accumulated number of participants	% of total sample population
	Autumn	Winter	Spring	Summer		
Unknown	53	10	6	5	74	42
Change in personal circumstance	9	0	1	0	10	6
Donkey suffered ill health or died	2	0	0	0	2	1
Donkey returned to Donkey Sanctuary *	2	1	1	0	4	2
Donkey sold	1	0	0	0	1	1

* Donkey adopted through The Donkey Sanctuary foster scheme

Figure 3.3. Distribution and number of survey participants

S – Scotland
W – Wales
R I – Republic of Ireland
N I – Northern Ireland
C I – Channel Islands
England
- A – North west
- B – North east
- C – West
- D – East
- E – South west
- F – South
- G – South east



3.3.2 Sample Population

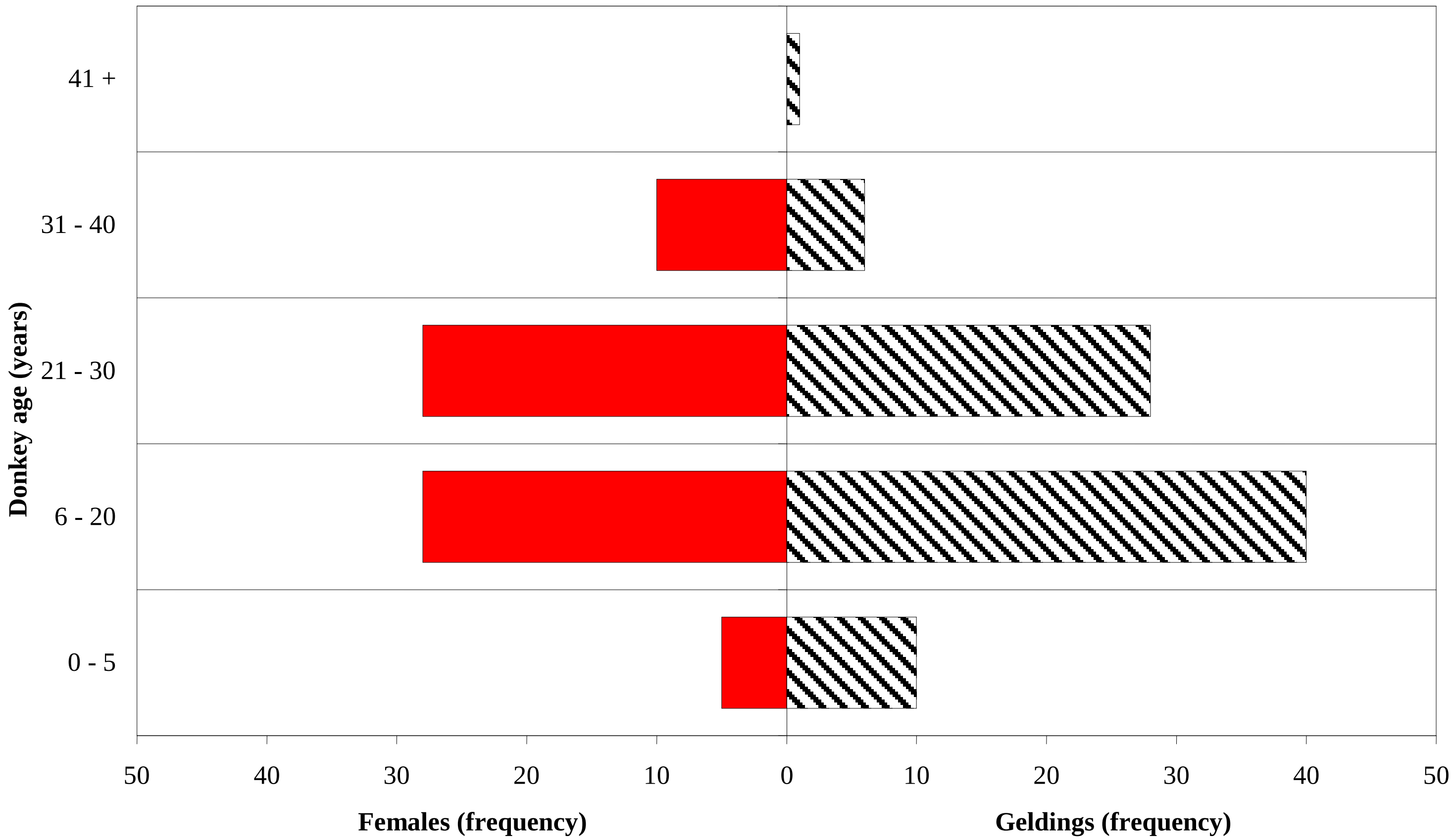
Distribution and Premises

Participants were recruited from all regions of the UK. Two participants were from the Channel Islands and one participant from the Republic of Ireland (Figure 3.3). Participants were distributed throughout mainland UK although the sample population was more densely populated in the West, East and South west of England. A total of 109 participants provided information of premises details. Of these 109 participants, 91 kept their donkey on private, non-commercial premises, 16 kept them on commercial farm land and only 2 kept their donkey on establishments purpose built for keeping equids. There was no effect of type of premises on the number of donkeys owned by participants, with the number of donkeys owned ranging from 1 – 3 donkeys on private premises and 1 - 4 donkeys on premises used for farming. The two participants keeping their donkeys on purpose built equine premises both owned 2 donkeys. In terms of number of donkeys owned per participant, 50% owned one donkey, 39% owned two donkeys, 9% owned three donkeys and only 2% owned four donkeys.

Donkey Details

Information on donkey age and sex was collected prior to the start of the survey and confirmed in question sheet 1. The sample population of 175 donkeys selected for the survey comprised 71 females, 84 geldings and 20 donkeys whose sex was not reported. Figure 3.4 shows the frequency of females and geldings in different age categories. The female donkeys were slightly older (mean 21 years, s.e. $\pm$ 1.0) than the geldings (mean 18 years, s.e. $\pm$ 1.0) and unknown sex (mean 18 years, s.e. $\pm$ 1.9) populations although these differences were not significant ($P>0.05$).

Figure 3.4. Population pyramid for the sample donkey population showing donkey age and sex



Donkeys were categorised as young (0 – 5 years), adult (6 – 20 years), early middle aged (21 – 30 years), late middle aged (31 – 40 years) and elderly (>40 years). Shown in Figure 3.4, donkeys ranged from 18 months to 43 years, with adult donkeys comprising 45% of the sample population. The percentage of the population comprised from young donkeys (9%) and late middle aged donkeys (11%) were similar. The number of late middle aged donkeys (17) was significantly lower than the number of early middle aged donkeys (56), suggesting that many donkeys may die below the age of 31 ($P<0.001$).

Condition Score

Body condition score 3 (on a scale of 1 to 5) was the most frequently reported condition score during all seasons, 61, 71, 71 and 68% of the sample donkey population during autumn, winter, spring and summer, respectively (Figure 3.5). Score 4 was the second most reported condition score, ranging from 22% of the sample population in February and March up to 32% in September. Considerably less donkeys were reported as being underweight (score 2) or obese (score 5). No donkeys were recorded as body condition score 1 in any month of the survey.

Compared to summer, the number of condition score 3 donkeys increased in autumn by 8%. This increase was due to 5 donkeys losing condition from condition score 4 and 5 donkeys gaining condition from condition score 2. During winter a loss of condition in 5 donkeys resulted in a further decrease in the number of donkeys of score 4 and a rise in the number of score 3 donkeys. These loses were most frequently reported in December. A decrease in the number of donkeys of condition score 3 in spring was due to a donkey previously in this category increasing to condition score 4. Four donkeys also lost condition changing from score 3 to score 2 causing the 2% rise in score 2 reported in March and April. During the summer condition scores stabilised with the least number of donkeys changing body condition.

3.3.3 Husbandry Practices

Housing

Participants of the survey managed their donkeys using one of three housing systems; a combination system (pasture access for part of the day, restricted to yard or stable for remainder of the day), extensive system with 24 hours pasture access (shelter available at all times) or intensive system (donkey housed or yarded all day with no pasture access). During all months the combination system was the most frequently used (Table 3.3). The number of owners managing their donkey extensively increased significantly in summer compared to winter ($P<0.001$), and probably reflects changes in pasture availability and weather conditions during the different seasons. Managing donkeys intensively was only reported in the colder, wetter months of the year, from October until March. The UK distribution of owners managing their donkeys extensively and intensively was not specific to areas of the country. Straw, as a single bedding material or in conjunction with wood shavings or rubber matting, was the most common and only edible bedding type used throughout the survey. Providing shelter with no bedding was not common practice, although the percentage of owners not providing any bedding material increased from 2% in autumn and winter to 12% in summer.

Figure 3.5. Percentage of donkeys in each body condition score during each month

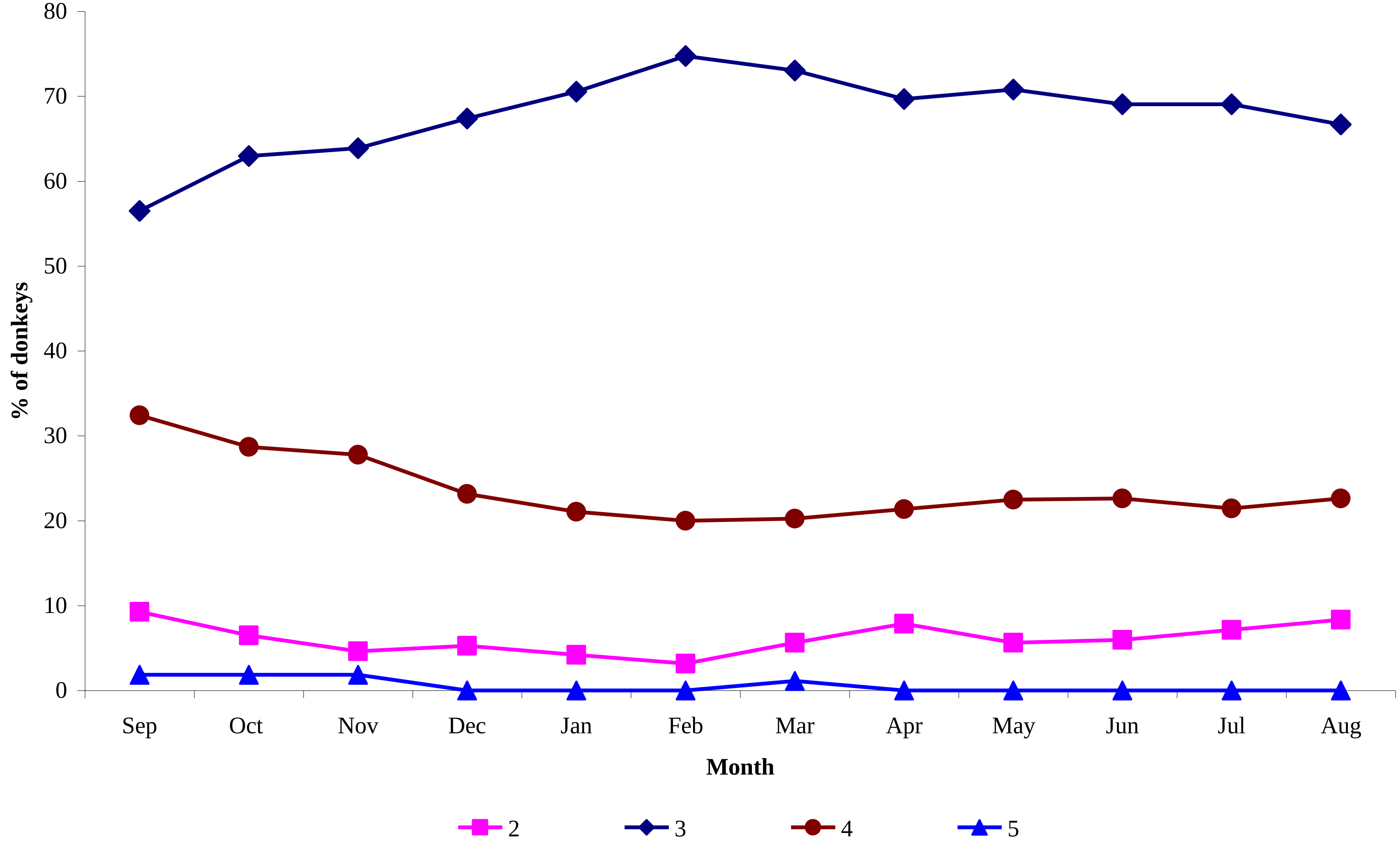


Table 3.3. Percentage of donkeys managed using each housing system

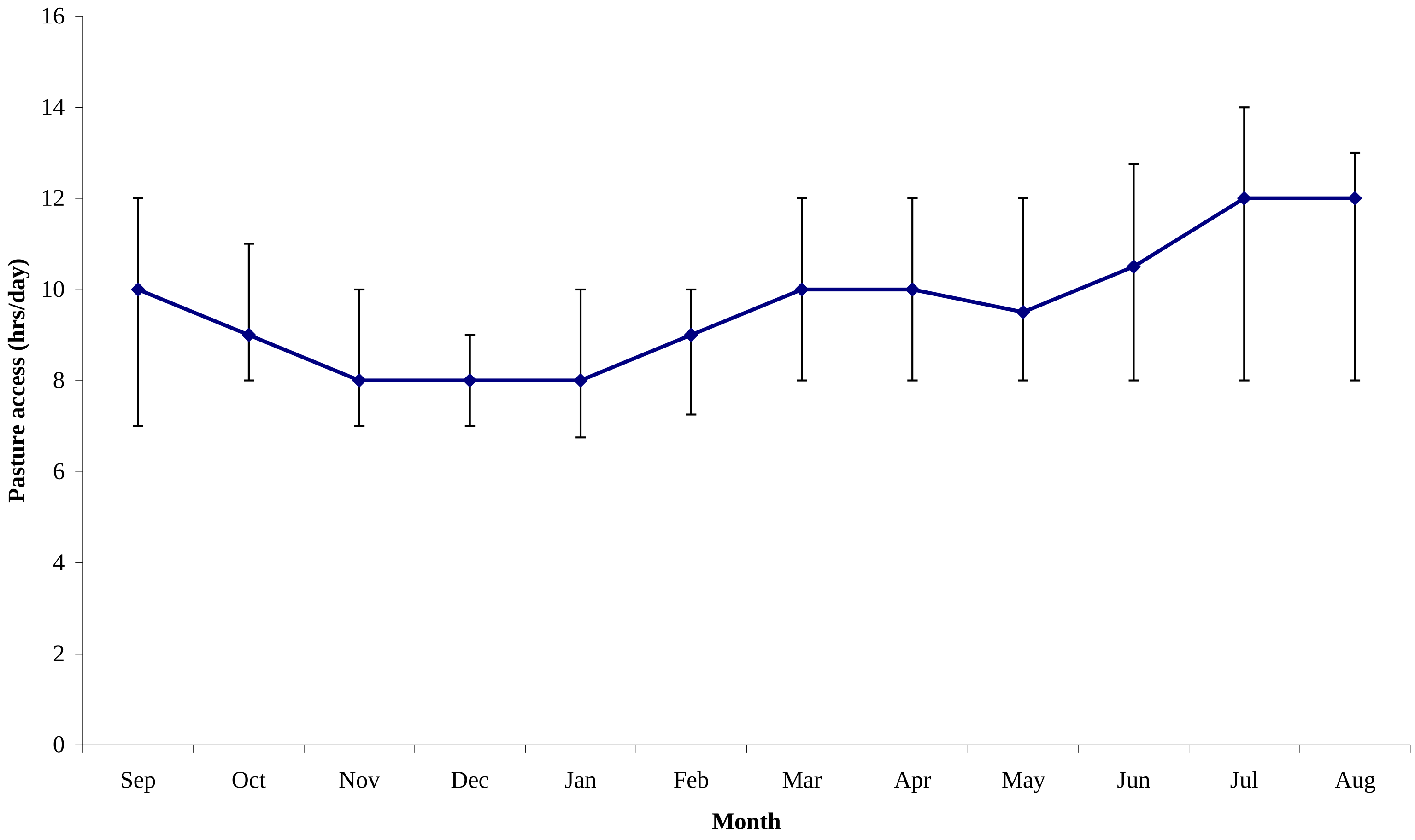
Season	Month	No. of animals	Combination system (%)	Extensive system (%)	Intensive system (%)
Autumn	Sep	108	60	40	0
	Oct	108	62	36	2
	Nov	108	67	31	2
Winter	Dec	97	72	24	4
	Jan	97	71	22	7
	Feb	97	70	25	5
Spring	Mar	89	75	22	3
	Apr	89	66	34	0
	May	89	67	33	0
Summer	Jun	84	54	46	0
	Jul	84	54	46	0
	Aug	84	54	46	0

Grazing

Pasture access times of donkeys managed using the combination housing system were significantly affected by season (Figure 3.6). During winter donkeys had significantly less daily pasture access time (median 8 hrs, interquartile range 7 - 10) than during the summer (median 11.5 hrs, interquartile range 8 - 13) ($P<0.001$). Grazing times during autumn and spring months were statistically similar ($P=0.067$).

Restricting the area of grazing pasture available to their donkeys was another method used by owners to manage pasture access. On average, 62% of owners using the combination system, and 59% of owners using the extensive system, restricted their donkey to less than 0.5 hectares (ha) grazing area. The percentage of donkeys grazing larger areas decreased as grazing area increased. On average only 11 and 13% of donkeys managed using the combination and extensive systems grazed areas 1 – 2 ha. A trend common to both systems was a decrease in grazing area in the spring and summer.

Figure 3.6. Pasture access times of donkeys (54 to 75% all donkeys, Table 3.3) managed using a combination system on a monthly basis (median, interquartile range)



Exercise

The percentage of owners exercising their donkeys ranged between 10 and 15% throughout the survey (Table 3.4). Of the donkeys exercised, leading in-hand was the most common method used over riding and driving. The majority of exercised donkeys worked for less than 2 hours per week throughout the survey, with only 6 donkeys working between 3 and 6 hours per week.

Table 3.4. Percentage of owners exercising their donkeys during each month

Season	Month	No. of donkeys	Percentage of donkeys exercised
Autumn	Sep	108	15
	Oct	108	13
	Nov	108	11
Winter	Dec	95	13
	Jan	95	13
	Feb	95	12
Spring	Mar	89	12
	Apr	89	10
	May	89	14
Summer	Jun	84	12
	Jul	84	11
	Aug	84	12

3.3.4 Feeding Practices

Composition of the diets fed by owners varied greatly between donkeys, and to a lesser extent between months. Fifty seven different feeds were offered to the donkeys during the survey, comprising of 37 different commercially produced concentrate feeds, 4 straight feeds (oats – whole and rolled, barley, sugar beet, bran), 11 types of chaff (dried, chopped forages), hay, haylage, and 3 types of straw (barley, wheat, oat). The DE content (MJ/kg DM) of food types are shown in Table 3.5.

Table 3.5. Percentage of owners feeding each food type during each month

Season	Month	No. of animals	Feed Type (DE content MJ/kg DM)					
			Concentrate (7.5 – 14.0*)	Straight (10.7 – 15.4)	Chaff (7.0 – 10.4)	Hay (7.2 – 9.8†)	Haylage (5.0)	Straw (3.0 – 8.5†)
Autumn	Sep	108	39	9	31	45	1	60
	Oct	108	41	12	33	53	3	60
	Nov	108	42	14	37	62	4	62
Winter	Dec	97	39	14	36	66	1	66
	Jan	97	38	15	36	69	2	69
	Feb	97	40	16	37	69	2	69
Spring	Mar	89	40	10	33	65	3	66
	Apr	89	38	4	31	61	2	69
	May	89	29	3	29	45	2	67
Summer	Jun	84	33	4	31	38	0	62
	Jul	84	31	4	30	40	0	55
	Aug	84	31	2	32	40	0	56

DE: Digestible energy
***** MJ/kg as fed
† DE value gained from samples provided by owners

Diets offered to donkeys were forage based with straw and hay being the most frequently fed food types to donkeys in each housing system during all months (Table 3.5). Haylage was not a common food offered to donkeys. Chaffed forages and concentrate feeds were fed by a similar number of owners throughout the survey and were the main dietary component fed to donkeys after forage. High energy straight feeds were fed by a small number of owners throughout the survey, with the frequency of feeding straight feeds being higher during the colder months from October to March.

Seasonal Feeding Trends

Straw was the predominant food fed to donkeys throughout the survey. Significantly more owners fed straw during winter and spring compared to autumn and summer ($P=0.001$). Feeding straw *ad libitum* was common practice during all months of the survey (Table 3.6), although significantly more owners offered straw in unrestricted amounts during autumn compared to all other seasons ($P<0.05$). The feeding of hay was common to most donkeys during all seasons. More owners fed hay during the colder months from October to April, with a significant increase in the feeding of hay in winter compared to summer ($P<0.01$). Hay was most frequently fed *ad libitum* to donkeys throughout the survey (Table 3.6), although the number of owners feeding restricted amounts increased in spring and summer ($P>0.05$). Of the donkeys fed restricted amounts of hay during spring and summer, 55% were fed less than 1kg of hay during spring, increasing to 74% in summer.

The feeding of chaffs was more common in winter compared to spring and summer ($P<0.05$). Most frequently less than 1kg of chaff was fed per day throughout the survey. Chaffs were fed *ad libitum* from October through until May by an average of 23% of owners each month.

The number of owners feeding concentrates gradually reduced throughout the survey with a significantly lower proportion of owners feeding concentrates at the end of the survey (summer) compared to at the start (autumn) ($P<0.05$). Concentrate feeds comprised only a small proportion of the donkey's diet with most owners feeding less than 0.5 kg concentrate feed per day (65, 58, 59 and 61% of owners during autumn, winter, spring and summer, respectively). Straight feeds were always fed in quantities less than 0.5kg per day.

Table 3.6. Mean percentage of owners feeding straw and hay *ad libitum* during each month

		% of owners feeding *ad libitum*	
Season	**Month**	**Straw (*n*)**	**Hay (*n*)**
Autumn	Sep	82 (65)	76 (49)
	Oct	82 (65)	75 (57)
	Nov	88 (67)	76 (67)
Winter	Dec	77 (64)	79 (64)
	Jan	79 (67)	76 (67)
	Feb	78 (67)	76 (67)
Spring	Mar	80 (59)	69 (58)
	Apr	84 (61)	67 (54)
	May	77 (60)	70 (40)
Summer	Jun	77 (52)	72 (32)
	Jul	76 (46)	68 (34)
	Aug	70 (47)	71 (34)

n: number of donkeys fed straw or hay each month

Effect of Housing System on Seasonal Feeding Trends

During all seasons, except winter, a similar number of owners fed straw and hay to donkeys managed using the combination and extensive housing systems. On average 63% of owners using the combination system, and 66% of owners using the extensive system, fed straw during autumn, spring and summer. The number of owners feeding straw using the extensive system increased significantly in winter to 95% ($P<0.01$). In contrast, the number of owners feeding straw in winter using the combination system remained similar to that during other seasons (65%). A similar trend was also observed for the feeding of hay. The average number of owners feeding hay using the extensive system increased from 48% during autumn, spring and summer to 92% during winter ($P<0.01$). The number of owners feeding hay using the combination system did not differ statistically between seasons.

Housing system had an affect on the quantities of forage fed to donkeys. More owners using the combination system fed straw ($P<0.05$) and hay ($P<0.01$) *ad libitum* compared to owners using the extensive system. On average, 82 and 75% of owners using the combination system offered straw and hay *ad libitum* each season, respectively. Comparative figures for owners using the extensive system are 75 and 67%. Seasonal differences in the number of owners feeding forage *ad libitum* were only reported for those using the extensive system with owners feeding significantly less straw *ad libitum* during winter and summer ($P<0.01$).

Housing system affected the feeding of concentrates. During all seasons, except winter, more owners using the combination system fed concentrate feeds compared to those using the extensive system ($P<0.05$). Most frequently, owners using the combination system fed less than 0.5kg concentrate feed per day, 67, 64, 67 and 76%

of owners during autumn, winter, spring and summer, respectively. Corresponding values for owners using the extensive system are 59, 39, 35 and 33%, respectively. The numbers of owners feeding less than 0.5kg of concentrates in the extensive system were significantly lower compared to the combination system and in winter, spring and summer compared to autumn (P=0.01).

3.4 DISCUSSION

3.4.1 Response Rate

Replies to the survey decreased throughout the duration of the study. The reasons for the majority of owners not returning questionnaires were unknown, and as no arrangements had been made to follow up non-returns due to time constraints, it is difficult to speculate as to why so many participants were unable to complete the questionnaires. Of the reasons provided by participants for not returning questionnaires, a change in personal circumstances was the most common. All participants experiencing a change in their personal circumstances highlighted a lack of time, or reduced physical ability due to ill health, as the reason for not being able to complete the questionnaires. The requirement to undertake practical activities such as heart girth measurement meant that owners experiencing such problems would not have provided completed questionnaires.

A recent postal survey of the management practices used by horse owners in the UK (Hotchkiss *et al*., 2007) gained a response rate of 61%, similar to that achieved in this study in season 1 (62%). An earlier postal survey of how horses were managed in Scotland and the northern counties of England (Cumbria, Westmorland, Northumberland and Durham), produced a response rate of only 40% (Mellor *et al*., 1999). Therefore, the lowest response rate of 48% reported in this study was relatively good, and similar to those previously reported for surveys of horse populations.

3.4.2 Sample Population

Distribution and Premises

Distribution of the sample population varied from region to region although all areas of the UK were represented. The keeping of donkeys predominantly on private premises suggests that donkeys are mainly kept in rural areas as owners had sufficient land to manage their donkey throughout the year. The keeping of donkeys on purpose built equine premises by only 2 owners may suggest that donkeys are not catered for on commercial equine enterprises, that owners do not want to keep their donkeys with horses and ponies, or that fewer owners keeping their donkey on commercial equine premises were included in the survey. Reasons for choice of premises were not recorded. One reason why donkeys may not be kept on commercial equine enterprises is the small area of pasture many owners restrict their donkey to graze. Restricting donkeys to less than 0.5 ha of pasture was common during all months of the survey, however, the grazing area for horses is recommended at 0.5 – 1 ha per horse (Pilliner, 1992), thus the provision of small grazing areas may not be available or practical on commercial establishments.

Information gathered on the number of donkeys owned by participants showed that half of the sample population owned only one donkey. However, during all seasons field companions were most frequently other donkeys. This suggests that owners allowed donkeys owned by other people to graze their land. Horses and ponies were also frequently reported as field companions, although it is uncertain if these horses and ponies were also owned by the donkey owner. Ownership and cohabitation of donkeys with horses and ponies could result in the same husbandry and feeding practices being used for both species, resulting in donkeys being fed similar diets as horses.

Donkey Details

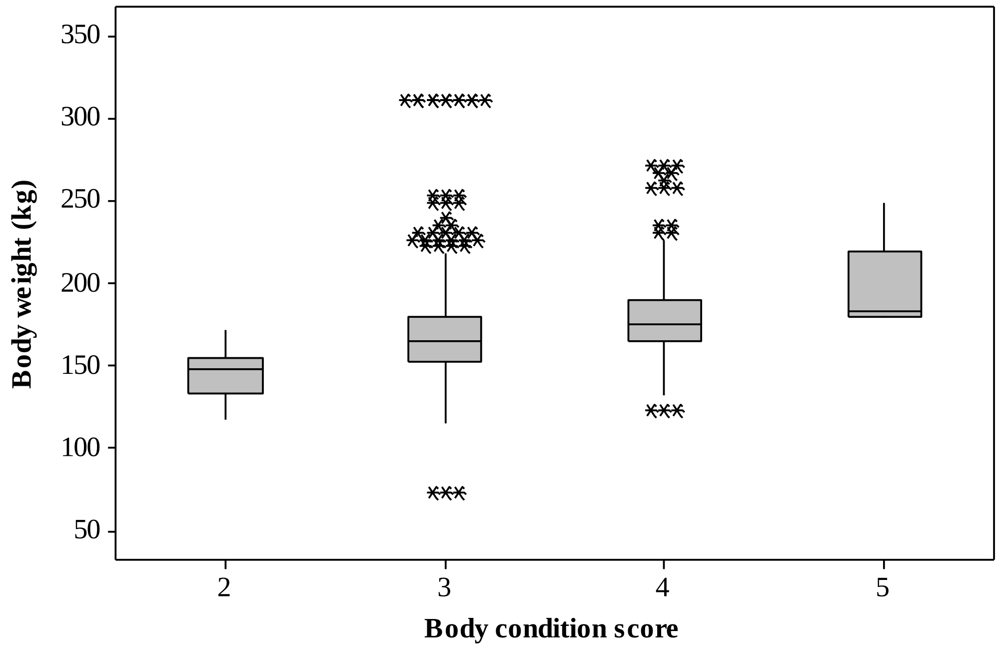
Results from this survey indicate that the donkey population within the UK is comprised equally of geldings and females and that the majority of donkeys are aged between 6 and 20 years (mean 19 years). However, the predominance of Donkey Sanctuary foster donkeys in the sample donkey population probably influenced these results, as this is the age category in which most foster donkeys would be classified. The large proportion of Donkey Sanctuary foster owners in the survey may also have caused the dramatic decrease in donkeys aged 31 and above in the sample population. Only 9% of the sample population were less than 6 years old. This may be due to younger donkeys not being represented in the survey, either due to owners not being recruited, or not wishing to take part. Fewer younger donkeys may also represent fewer donkeys under the age of 6 being in the actual UK donkey population. Of the total UK donkey population in 2005 (9303 donkeys, National Equine Database, Warwickshire, UK), 40% (3707 donkeys) were in the care of The Donkey Sanctuary. The no breeding policy of the Donkey Sanctuary leads to all male donkeys in their care being castrated. Therefore the fewer number of young donkeys in the survey may represent a reduction in the breeding of donkeys in the UK that would reduce the UK donkey population dramatically over the ensuing years.

Condition Score

Results on condition score show the majority (57 – 74%) of donkeys surveyed were in ideal body condition (score 3 on a scale of 0 – 5), with the least number of donkeys being classed as obese. The proportion of donkeys classed as overweight however averaged 24%, indicating that a quarter of the UK donkey population are at an increased risk of suffering health problems associated with carrying excess body weight. The frequency (20 – 34%) of overweight (score 4 and 5) donkeys was similar to that reported for cats (Robertson, 1999; Allen *et al*., 2000), and dogs (Edney & Smith, 1986; Robertson, 2003) in developed countries. The donkey population surveyed in the present study, however, did have a lower incidence of obesity than a population of leisure horses (319 horses) in the south-west of Scotland (Wyse *et al*., 2008). Thirty five percent of horses surveyed between June and July 2005 by Wyse and colleagues were overweight (score 5 on a scale of 1 to 6), with a further 10% being obese (score 6). The high incidence of overweight horses was partly attributed to the time of year the horses were assessed. The authors speculated that the horse's body condition score would fluctuate throughout the year in response to changes in pasture growth and metabolic rate. The body condition of donkeys in the present study did decrease in winter and increase slightly in spring and summer, however, the proportion of overweight donkeys in the present study was considerably less than that reported for the horses (23 and 21% for June and July, respectively), even though the donkeys were assessed over the same time period (June to July 2005). The higher incidence of obesity in the horse population compared to the population of donkeys surveyed may be due to differences in the geographical areas surveyed in the two studies, or method of body condition score assessment.

In the study by Wyse *et al*. (2008) body condition score was assessed by the authors. Assessment of condition score by owners of the donkeys in the present study may have underestimated the frequency of overweight donkeys. Underscoring of body condition in horses is common, with approximately 30% of owners underscoring their horse's body condition (Personal Communication; T. Hollands, Dodson and Horrell Ltd, UK). Validation studies of condition scoring systems for cats, dogs and cattle, however, do show that when provided with training or guidelines on how to accurately assess condition score, assessments by owners and farm workers correlate well with those by trained professionals (German *et al*., 2006; Kristensen *et al*., 2006). The provision of guidelines on condition scoring donkeys to survey participants in the present study, should therefore, have reduced inaccuracies in body condition assessment. The finding that donkeys of higher body condition score were heavier, and not of larger body size (Figure 3.7), supports the results of body condition score gained from this survey.

Figure 3.7. Box and whisker plot of donkey body weights classified into body condition scores showing median, interquartile range and outlier values.



The accuracy of future studies of body condition may be increased further by using alternative terms to describe condition score of animals, particularly pet animals, to those used in the present study. The scoring systems for donkeys and horses use both a numbering and descriptive system, with animals being assessed as being either thin, in ideal condition or fat. However, the terms thin and fat are emotive, with terms fat and obese being negatively associated with health and social acceptance in humans (Maddox, Back & Liederman, 1968; Janssen *et al*., 2004). Keeping animals in fat and obese condition is also associated with poor health in animals, thus the same negative feelings are likely to be associated with owning overweight animals. Owners of overweight donkeys in the present and future surveys may be reluctant to score their donkeys as fat (score 4) and obese (score 5) leading to underscoring of body condition. A more objective system, using only numbers or letters to assess body condition, may reduce the negative association of scoring donkeys in fat and obese condition, leading to more accurate assessment of body condition. Any advice on reducing body condition score of donkeys should emphasize the health benefits of keeping donkeys in ideal body condition, reducing the negativity associated with owning overweight donkeys.

Differences in how donkeys and horses are managed may account for the potential differences in obesity levels between horses and donkeys. Hotchkiss *et al*. (2007) found that during summer, horses in the UK are managed more frequently with 24 hour access to pasture than donkeys. Depending on pasture quality and availability, the longer grazing times available to horses may promote excess energy intakes. From the same study it was revealed that during all seasons, hay was fed to a similar proportion of horses as it was to donkeys in the present study, but that concentrate feeds were fed to considerably more horses. Respectively 76, 64, 61 and 45% of horses were fed concentrates in autumn, winter, spring and summer, compared to 41, 39, 36 and 32% of donkeys. The continued feeding of concentrate feeds to horses in spring and summer, when pasture growth increases and horses have longer grazing times, is a likely cause of horses gaining excess body weight in these seasons and would explain the higher incidence of obesity reported in horses by Wyse *et al*. (2008) compared to that reported for donkeys in the present study, although further research into the quantities of foods fed to horses and donkeys is needed to confirm this assumption.

The cause of excess weight gain in the present study did not appear to be the feeding of high energy concentrate feeds. Of those donkeys recorded in condition score 3 and 4, respectively 71 and 72% were fed forage and only 27 and 23% were fed concentrate feeds. Surprisingly, 71% of donkeys recorded as condition score 2 were fed concentrate feeds compared to only 27% fed forage. Excess body weight in donkeys may therefore be related to quantities of foods fed rather than types of food fed, although analysis of the quantities of foods fed could not be carried out as many owners did not provide this information.

3.4.3 Husbandry Practices

The keeping of donkeys in a combination housing system with restricted access to pasture, was the most common system used by owners throughout the survey. This system was also reported to be the most common method of managing horses in the UK (Hotchkiss *et al*., 2007). The primary benefit of using a combination system is that it allows owners to regulate their donkey's access to pasture, therefore influencing intake of pasture and exposure to the outdoor elements. Allowing donkeys to graze for longer in summer, when grass availability is greatest, increases utilisation of pasture as a food source, potentially reducing the amount of supplementary food required by donkeys due to higher DM and DE intakes from grazing. Housing during inclement weather reduces daily pasture access time, and was more widely practiced in winter (median 8 hours per day at pasture) compared to in summer (median 11.5 hour per day at pasture). Shorter pasture access times are also reported in winter for horses and ponies in the UK (Mellor *et al*., 2001; Hotchkiss *et al*., 2007). The apparent preference for keeping donkeys in a combination system may have been influenced by an inability to provide a place for shelter within the grazing area, making it necessary for owners to house their donkeys for part of the day in order to provide a place for them to rest and to protect them from the sun, rain or wind.

Season also influenced the management systems used by owners. During winter the number of donkeys managed extensively decreased, with most donkeys changing to the combination housing system. During this period only 3 donkeys changed from having 24 hours pasture access to having no pasture access. Managing donkeys intensively was not common practice in the UK, probably due to the high cost and labour involved in housing donkeys 24 hours a day. The number of donkeys managed intensively increased in winter, and although not reported by all owners using this method, this may have been due to their donkeys suffering from the foot condition Seedy Toe, as the number of owners reporting this problem increased during this season. As Seedy Toe is a foot condition associated with animals standing on dirty, wet surfaces (Crane, 2008), more owners are likely to house their donkeys during winter with the aim of keeping their donkeys feet dry to prevent or treat Seedy Toe.

The area grazed by donkeys was not significantly influenced by management type, although a greater number of donkeys with 24 hours access grazed areas more than 1 ha. It could be that the area available to donkeys with 24 hours pasture access was greater than that grazed by donkeys with pasture access for only part of the day, to prevent over grazing and poaching of the land in wet conditions. Owners may also graze their donkey on larger areas of land to reduce the amount of supplementary food required by their donkey. However, Table 3.7 shows that the percentage of donkeys managed extensively receiving additional food as concentrates, chaffs or forage, which had access to more than 0.5 ha of pasture, was high during all months of the survey. This result suggests that although many owners manage the amount of grazing available to their donkeys, grazing area does not influence the feeding of other foodstuffs.

Table 3.7. Percentage of donkeys managed extensively receiving either concentrates, chaffs or forages each month.

		% of donkeys receiving additional foodstuffs	
Season	**Month**	**< 0.5 ha grazing pasture**	**> 0.5 ha grazing pasture**
Autumn	Sep	59 (27)	86 (16)
	Oct	65 (20)	93 (17)
	Nov	69 (16)	93 (16)
Winter	Dec	92 (12)	80 (11)
	Jan	100 (10)	80 (11)
	Feb	100 (10)	60 (11)
Spring	Mar	82 (11)	89 (9)
	Apr	91 (22)	100 (8)
	May	83 (24)	100 (8)
Summer	Jun	75 (24)	75 (15)
	Jul	69 (26)	70 (13)
	Aug	73 (22)	86 (17)

n: total number of donkeys managed with <0.5 ha and >0.5 ha grazing access each month

Reducing grazing area is used regularly by horse owners in an attempt to reduce pasture intake (personal observation). Results on grazing area indicate donkey owners use the same practice. The area grazed by donkeys in both the extensive and combination housing systems was affected by season, with more donkeys grazing less than 0.5 ha of pasture during spring and summer, probably as a response to increased grass growth. The effectiveness of reducing grazing area on grass intake has not been investigated directly in equids or ruminants. A reduced grazing area would only be effective if herbage availability per animal, and daily grazing time, were reduced enough to prevent compensatory increases in bite depth, weight and rate (Iason *et al*., 1999; Smith, 1999; Naujeck & Hill, 2003; Edouard *et al*., 2009). The concomitant increase in donkey grazing time in summer may counteract any effect of reduced grazing area in this season. Further investigation into the affect of grazing area and grazing time on grass intake by donkeys is warranted, as this would enable owners to maximise the efficiency of a husbandry practice that is already commonly used.

3.4.4 Feeding Practices

The survey showed that owners feed many different types and brands of feeds to their donkeys, although none of the commercially produced concentrate feeds or chaffed forages were designed specifically for feeding donkeys. On a metabolic body weight basis, donkeys have been shown to have lower maintenance DE requirements than ponies (Chapter 4), therefore feeding high energy feeds could result in excess weight gain. The feeding of concentrate feeds containing up to 14MJ DE/kg DM and alfalfa based chaffs (10.4MJ DE/kg DM), could result in maintenance energy requirements being satisfied from small quantities of food. Any additional food consumed by the donkey, in an effort to satisfy DMI requirements, would result in excess energy being consumed. An encouraging result from the survey was a reduction in the percentage of owners feeding concentrate feeds from May onwards. This may have been due to owners becoming more aware of the feeds they were offering to their donkey, and changes in their donkey's requirements due to measuring heart girth. An increased awareness of changes in their donkey's body condition, and thus body weight, was highlighted by many owners in the feedback forms. A reduction in the amount of supplementary food provided by owners, especially the unnecessary feeding of concentrates, would also reduce feeding costs, proving a further incentive for owners to reduce the amount of concentrates and chaffs offered to their donkeys.

The high percentage of owners feeding forages each month shows an excellent understanding owners have of the importance of feeding fibre to donkeys. The increased number of owners feeding hay from October until April indicates that owners also understand that forages are able to provide all or most of their donkey's required energy, even in the colder winter months when energy requirements increase (Chapter 4).

Seasonal Feeding Trends

The feeding trends recorded in this survey indicate that, in general, owners have a good basic understanding of both the dietary and behavioural requirements of their donkeys. The feeding of low energy straw *ad libitum* during all seasons enables donkeys to eat for extended periods of time and satisfy appetite whilst preventing excess energy intake. The greater number of owners feeding hay from October until April coincides with reduction in grazing quality and availability, and shorter grazing times for donkeys in the combination system. Hay may therefore be fed as a partial replacement for grass. The greater number of owners feeding hay in restricted amounts during spring and summer support this view, although the large percentage of owners continuing to feed hay *ad libitum* during spring (mean 67%) and summer (mean 68%) suggests that owners are unsure of how to adjust their donkey's diet and ration in response to changing pasture intake. Measurement of seasonal grass intake by grazing donkeys, and investigations into the affect of feeding supplementary foods on grass intake and grazing behaviour, would enable advice on feeding donkeys to account for pasture access.

The feeding of concentrates followed a similar pattern to that of feeding hay, with fewer donkeys receiving concentrates from May until August. The reduced feeding of concentrates in spring and summer may have been a response to increased pasture availability, suggesting that owners understand the nutritional value of grass. It may also have been due to an increased awareness by owners of their donkey's nutritional requirements and the types of foods they offer to their donkey. Continuation of the survey would have indicated for which of these reasons owners reduced the feeding of concentrates during spring and summer.

Effect of Housing System on Seasonal Feeding Trends

Housing system affected the diets fed to donkeys and seasonal feeding trends, suggesting that owner understanding of feed types and their nutritional value differs between systems used. Owners managing their donkeys with 24 hour pasture access adjusted the diets fed to their donkeys in response to season, increasing the feeding of straw and hay in winter. In contrast, the number of owners feeding straw and hay using the combination system did not vary between seasons. Owners using the combination system adjusted pasture access time and area as apposed to diets fed. In addition, throughout the survey more owners using the combination system fed concentrates, although in smaller quantities than owners using the extensive system. The feeding of concentrate feeds during every month, combined with adjustment of grazing access and not foods fed, suggests that owners using the combination system are more uncertain about appropriate diets and rations to feed to their donkey. It may be that owners are aware of changing pasture quality but are unsure what to feed their donkeys when they are stabled. Further investigation into diets and rations fed to donkeys, and the reasons why owners select individual feed types, would help to answer these questions.

3.4.5 Limitations of Methodology and Critique of Results

The aim of the survey was to gather information on the body condition score and management of donkeys in the UK, that could be used to make feeding guidelines for donkeys of practical use to owners and that are applicable to the wider UK donkey population. An assessment of how methodologies used effected results is therefore essential and will help to maximise the effectiveness of future surveys of equine husbandry.

Representation of the Wider Population

Generally, the larger the sample size of a postal survey the greater the accuracy and lesser the bias with which the total population is represented, although the number of participants will be dictated by the resources available to the project. At the time of recruiting participants for the present survey (April to July 2004) exact numbers of donkeys in the UK were not available as equines were not legally required to be registered with the National Equine Database (NED, Warwickshire, UK) until 2005.

Starkey and Starkey (2000) approximated 10,000 donkeys in the UK in 1996, thus using equations 3.3 and 3.4, a sample population of 370 participants would be ideal (95% confidence level, 5% confidence interval). However, the non-registration of donkeys in the UK made recruiting donkey owners difficult as there was no direct source of contact to owners, except to those on the Donkey Sanctuary foster scheme. As a result of the difficulty in contacting owners only 178 participants were recruited. Donkey Sanctuary foster owners provided 164 of the 178 participants with the remaining participants being recruited through adverts in equestrian publications. The estimated number of donkeys in the UK during 2004 was 9303 (NED, 2005), therefore the sample population of 178 owners and donkeys was 2% of the total population. Future studies of equine populations in the UK should utilise the NED to gain accurate population statistics and may be able to use the NED as a point of contact to owners, although to date this facility is not available.

Equation 3.3

$$\text{Sample size (ss)} = \frac{Z^2 \times p \times (1 - p)}{d^2}$$

Where:
Z: Z value (1.96)
p: percentage picking a choice (0.5)
d: confidence interval (0.05)

Equation 3.4

$$n = ss / 1 + \frac{(ss - 1)}{N}$$

Where:
n: number of survey participants
ss: sample size
N: total population

Recruitment of 2% of the total donkey population in the present survey may have reduced the accuracy with which donkeys in the UK, and how they are managed, were represented. However, recruitment of donkeys of all ages from all areas of the UK, managed using different housing systems and fed a variety of different diets, showed results were gained from a diverse sample population, and suggests that the sample population was representative of donkeys managed using common husbandry practices and of owners with access to a variety of resources and with varying levels of knowledge of donkey requirements. The results from the present survey are therefore thought to be representative of the total UK donkey population.

Questionnaire Design

The questionnaire was designed to maximise the amount of information gathered on the many factors influencing how donkeys are fed. Upon completion of the survey and collation of the data, it is apparent that certain areas of donkey management were of greater relevance to how donkeys were fed than others. More detailed questioning of certain aspects of donkey husbandry would have yielded more useful information. For example, although information on the number of donkeys kept on edible bedding was useful, further questioning to find out if owners accounted for intake of straw bedding when feeding their donkeys was not undertaken. Information on the condition and management of grazing pasture aimed to account for the potential intake from grazing and browsing. However, estimation of pasture quality was difficult due to only an approximate assessment of pasture condition by owners. In addition, no information was gathered on the quantity and species of grasses present. Laboratory analysis of pasture nutrient content provided quantitive assessment of pasture quality without owners having to answer any questions and therefore was less subjective. In view of this, the questions on pasture management and quality and on trees and shrubs could have been excluded.

3.5 CONCLUSIONS

A principle requirement of this study was to gather representative information on the UK donkey population. Recruitment of participants from all regions of the UK suggests that aim was achieved although recruitment of 92% of the sample population from Donkey Sanctuary foster homes is likely to have influenced results. Donkeys appear to be kept mainly on private premises with donkeys, horses and ponies as field companions. The keeping of more than one equid, combined with the provision of daily pasture access throughout the year, shows that owners had adequate grazing land, indicating that donkeys are predominantly kept in rural areas.

The donkey population appears to be comprised equally of geldings and females. The finding that more donkeys were aged between 6 and 20 years than any other age group suggests that the donkey population in the UK may decline in future years due to lower numbers of younger donkeys. However, this result was likely affected by the use of Donkey Sanctuary foster homes. The health status of donkeys in the UK appears to be good. Only 3 cases of laminitis, 1 case of colic and 1 case of hyperlipaemia had been previously experienced by donkeys in the sample population. The only ongoing health concerns were dental problems in one donkey. The ideal condition score of the majority of donkeys in this study may be the reason for the good health of survey donkeys. An increased frequency of under and overweight donkeys would likely coincide with an increased incidence of dental problems and laminitis cases, respectively.

Donkeys in the UK are managed in a similar way to horses and ponies with access to pasture for at least part of the day. Pasture access time is influenced by season, with donkeys spending longer time at grass in the spring and summer. Keeping donkeys continuously housed or yarded is not common practice in the UK and generally only used in months of inclement weather.

The provision of daily pasture access to the majority of donkeys in this survey shows that pasture has the potential to provide a large percentage of daily DM, DE and nutrient intake, although the feeding of many different types of foods indicates that owners are unsure of what to feed their donkeys, and quantities required, to supplement pasture intake. It is therefore important to quantify the contribution of daily pasture access in satisfying intake requirements if feeding recommendations are to be of practical use to donkey owners. Investigations into pasture access time and area grazed will provide the most practical results, and will enable owners to more accurately estimate when the feeding of forages, chaffs and concentrates to supplement pasture intake is actually necessary, potentially reducing feeding costs and ensuring donkeys do not become overweight.

The finding that most donkey owners fed forage based diets with only small amounts of concentrates is encouraging as it shows that owners understand that donkeys need to consume fibre based diets. The increased feeding of forages and not concentrates in winter also indicates that owners recognise the value of forage for providing energy to their donkeys. The concentrate feeds that were offered to donkeys, however, were of high energy content compared to requirements, making the feeding of concentrate feeds a potential risk factor to donkeys becoming overweight.

The final aim of the survey was to assess the state of owner knowledge of donkey nutritional requirements. The feeding of forage as the principle food type throughout the survey and to donkeys in all housing systems, combined with the ideal condition score of many of the donkeys implies that the owners surveyed in this study understand the importance of keeping their donkey at a healthy weight and which food types are most suited to feeding to donkeys. However, from the feedback forms, lack of information on how to feed overweight donkeys, especially when housed in a group or with a thin donkey, makes feeding donkeys with specific weight problems difficult. Other problems identified were lack of feeding advice for older donkeys, lack of information on general health conditions (foot and skin problems) and problems with vets and farriers not distinguishing between the needs of donkeys, horses and ponies.

3.5.1 Future Work

This study has highlighted two main areas of donkey management requiring further investigation. Primarily the contribution of daily pasture access to donkey DM and DE intakes should be quantified as the majority of donkeys in the UK are managed with access to pasture on a daily basis. Assessment of the effects of grazing time and grazing area on grass intake, combined with recommendations for DM and DE intakes, will enable feeding guidelines for donkeys that are of practical use to owners to be compiled. Secondly, accurate measurements of the quantities of foods offered to donkeys and assessment of the reasons why owners feed different food types are essential. Identifying the aspects of feeding donkeys that owners may not understand or have difficulty with will enable advice on feeding donkeys to be targeted to these specific areas.

CHAPTER 4
THE EFFECTS OF SEASON AND SEX ON DIGESTIBLE ENERGY REQUIREMENTS OF DONKEYS IN THE UK

4.1 INTRODUCTION

Results from the survey (Chapter 3) indicate that owners in the UK require guidance on diets and rations to feed to meet their donkey's nutritional requirements. Most owners were maintaining their donkeys in healthy body condition, although being overweight was found to be quite common (average 24% overweight) in the sample population. If energy requirements of donkeys are lower than those of horses and ponies, the feeding of concentrate feeds to donkeys may be unnecessary, as diets of forage and pasture are likely to meet DE requirements whilst satisfying voluntary food intake. Selection of suitable diets and formulation of correct rations for donkeys requires knowledge of donkey DE and DM requirements. From determination of the energy requirements of donkeys in the UK, feeding guidelines for donkeys could be compiled, enabling owners to estimate their donkeys DE and DM requirements with greater accuracy, and select the most appropriate food types for their donkey's nutritional requirements.

The only long term study (13 months) determining the maintenance energy requirement of donkeys was carried out in Mexico (Carretero-Roque *et al*., 2005). Comparisons of results with horse feeding recommendations (NRC, 2007) show considerable differences. Horse recommendations overestimated DE requirements of Mexican donkeys in the study by an average of 54% (1.8MJ/kg $BW^{0.75}$), indicating that donkeys have lower maintenance energy requirements than horses and ponies (Carretero-Roque *et al*., 2005). The DE calculations gained from the study of

Mexican donkeys are a useful means of estimating DE requirements of UK donkeys. However, the small size of the donkeys used in the Mexico study (97 – 133kg BW) and possible differences in ambient temperature and humidity between the UK and Mexico make it necessary to calculate separately the energy demands of donkeys in the UK.

4.1.1 Outline of Study

The study determined the DM and DE intakes by mature donkeys maintaining body weight. Intakes were measured during 4 recording periods, one for each UK season. The weeks between recording periods were classed as rest periods, when the donkeys were managed as one group. Each recording period consisted of an equilibrium phase, used to stabilise the donkey's body weights through adjustment of individual rations, followed by an intake recording and total faecal collection phase. Dry matter and DE intakes were measured during each UK season to assess for seasonal changes in intake. Geldings and female donkeys were used to assess for any effect of sex on DM and DE intakes. Donkey body weights were measured daily during the recording and rest periods, and averaged on a weekly basis to calculate any changes in body condition. Changes in body weight over time (study days) were representative of excesses or deficiencies in energy intake, as energy consumed in excess of maintenance requirements by mature, non-working, non-breeding donkeys will be stored as fat. The study aimed to:

1. Determine the maintenance DE requirements of mature donkeys in the UK

Research Objectives

- Measure the DEI of male and female donkeys maintaining body weight when fed forage diets using a 5 day total faecal collection method

- Measure the seasonal variation in DEI of donkeys in Devon through adjustment of rations fed to maintain donkeys at stable body weights

4.2 MATERIALS AND METHODS

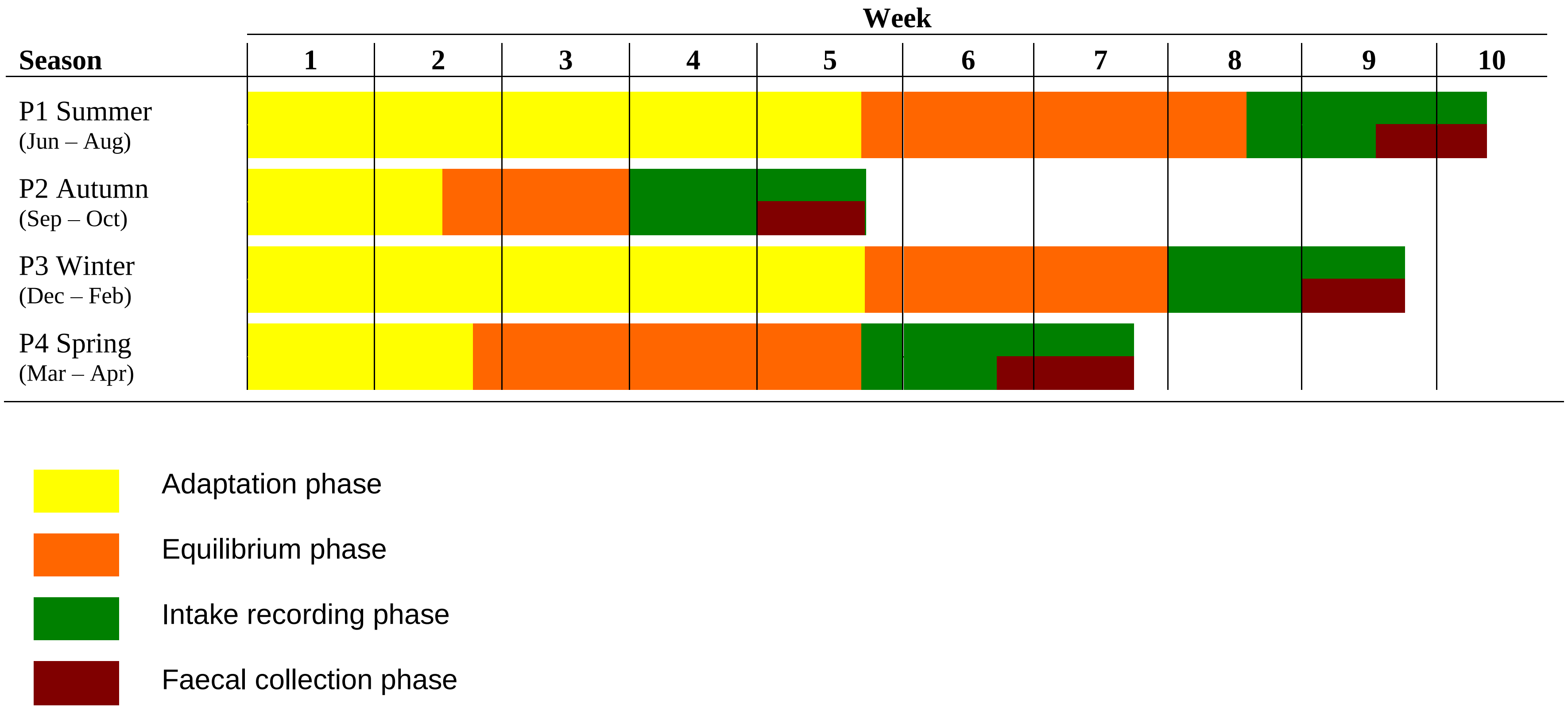
4.2.1 Experimental Design

The experiment was carried out between May 2003 and June 2004 at Hurfords Farm, part of The Donkey Sanctuary, Sidmouth, Devon, in the South west area of the UK. The experimental period was divided into 4 seasonal recording periods; Period 1 (summer, June 4th – August 8th 2003), Period 2 (autumn, September 29th – October 31st 2003), Period 3 (winter, December 15th 2003 – February 13th 2004), Period 4 (spring, March 16th – April 30th 2004). Each recording period was divided into 4 phases; adaptation, equilibrium, intake recording and 5 days total faecal collection (Figure 4.1). Between recording periods the donkeys were managed and fed as a group, and allowed access to pasture during the summer months. Prior to the adaptation phase of Period 1 the donkeys were given 8 days to become accustomed to their new companions and the experiment site.

Adaptation

The adaptation phase was used to introduce the donkeys to their individual stables gradually and accustom them to eating out of individual feeding troughs. This phase was necessary because changes in routine and environment can induce stress related hyperlipaemia in donkeys (Personal Communication; Catherine Muir, The Donkey Sanctuary, UK). The time the donkeys spent in their stables gradually increased, reducing the donkeys pasture access and socialisation time. The amount of food the donkeys were offered from large group feeders in the loafing/yard area (Figure 4.2) was gradually reduced to zero over a period of 33 days. Correspondingly the amount of food that was offered in the individual stables was increased.

Figure 4.1. Calendar of experiment schedule



Donkeys were eventually housed individually overnight and for 6 hours during the day. A longer adaptation phase for Period 1 was required as the donkeys were not accustomed to being in confined spaces for any great length of time. This phase took 33 days for Period 1 and 11, 29 and 13 days for Periods 2, 3 and 4, respectively. The extended adaptation phase for Period 3 was required to stabilise body weights as a number of donkeys lost weight during the preceding rest period.

Equilibrium

The equilibrium phase began the first night the donkeys were housed in their individual stables. The purpose of this phase was to stabilise the donkeys' body weights through adjustment of individual rations offered. During this period, strict daily management and feeding routines were established and adhered to until the end of each recording period (Table 4.1). Following the same routine during each period ensured variations in DM and DE intake were due to variations in requirements and not changes in feeding times or restriction of eating time due to a different routine. The equilibrium phase lasted 20 days in Periods 1 and 4, 19 days in Period 3 and 9 days in Period 2. The shorter phase during Period 2 was due to the donkeys having been used in another experiment (Chapter 5) during the previous rest period.

Intake Recording

Intake recording took place over the final 13 days of each recording period. Prior to the start of intake recording all stables were thoroughly cleaned. Intake recording started at 09:30h on Day 1 and continued until 09:30h on Day 13. Collection of food refusals started at 09:30h on Day 2 of this phase and continued until 09:30h on Day 13 of each recording period, resulting in 12 days intake recording. Food refusals were collected at regular intervals throughout each 24 hour period to prevent contamination of faecal deposits. This phase enabled the daily DMI for each donkey to be calculated. It was important to achieve a constant daily intake prior to the start of faecal collection to ensure the results for faecal output were representative of constant daily DMI.

Faecal Collection

Total faecal collection took place over the final 6 days of each recording period. Collection started at 09:30h on day 8 of intake recording and was complete at 09:30h of the final day of each recording period, resulting in 5 days total faecal collection. Faecal deposits were collected regularly throughout each 24 hour period.

4.2.2 Animals

Selection of Experimental Animals

The experiment was to determine the DE requirements of mature donkeys for maintenance, therefore experimental donkeys were of mature age (10 – 26 years), in good health and of ideal condition score (score 3 on a scale of 5). To facilitate intake calculation, experimental donkeys were managed so as not to be reliant on daily concentrate feeds (See 4.2.5, Sample Collection). Male and female donkeys were used to assess for the affect of sex on DE requirements.

Experimental Animals

Twenty donkeys, 10 geldings, 10 females, were selected for the experiment. Prior to the start of the first recording period two bonded females were removed from the experiment due to one donkey suffering health problems unrelated to the experiment. The remaining 10 gelding and 8 female donkeys were used for recording periods 1 and 2. Prior to Period 3, two new female donkeys joined the experiment and were used in Periods 3 and 4 resulting in 10 females during both of these recording periods. During the rest period prior to Period 3, one male donkey lost considerable weight and required concentrate feed to supplement his intake. It was felt that removing this additional food source could compromise his health, therefore he was removed from the experiment for Period 3. A further two geldings were excluded from Period 3 as they were suffering from laminitis thought to be induced by changes in weather (Personal Communication; Catherine Muir, The Donkey Sanctuary, UK). Both donkeys recovered although one was excluded from Period 4 due to a second case of laminitis. The resulting number of male participants for Periods 3 and 4 were 7 and 9, respectively. Throughout the experiment the donkeys followed routine farriery, dental, vaccination and parasitic treatments.

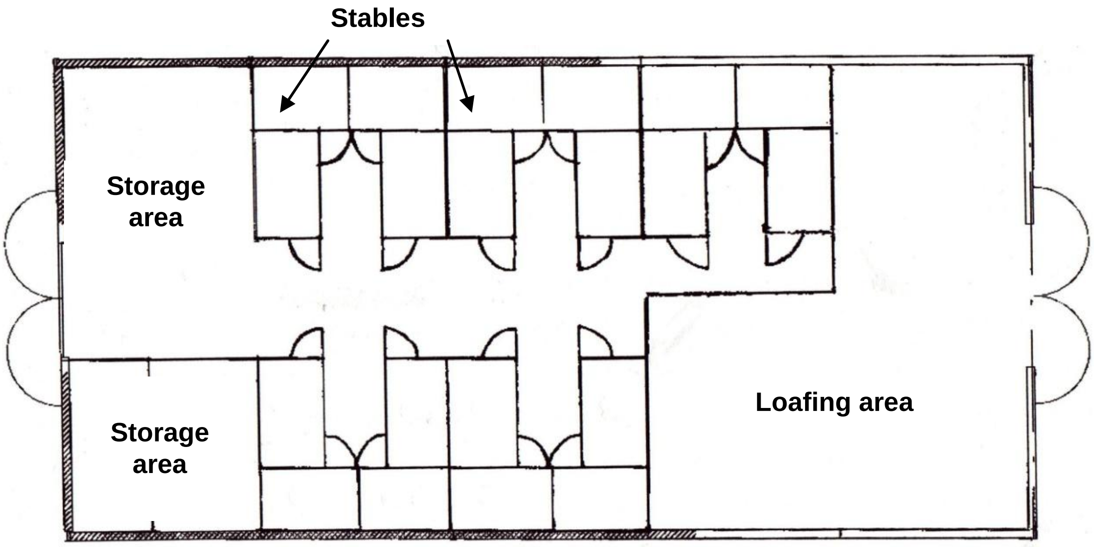
4.2.3 Housing

The experiment took place in an open span barn. Within the barn was an area for food storage, 20 individual stables and a loafing area opening onto a large concrete yard at the rear of the barn (Figure 4.2). Adjacent to the yard was grazing land approximately 0.7 ha, available to the donkeys during the summer rest periods.

Stables

Each donkey was allocated an individual stable (7.6m^2) for the duration of the experiment. Donkeys with close friendship bonds were housed in adjacent stables to permit visual and physical contact and reduce separation stress. Each stable had a wooden corner feeding trough and an automatic water drinker. The walls of the stables were made of metal bars covered by wooden kicking boards to a height of approximately 1.2m. The metal bars continued for a further 0.3m above the kicking boards to prevent animals leaning over into adjacent stables. Metal caps covered the tops of the kicking boards to prevent wood chewing.

Figure 4.2. Diagram of barn showing position of individual stables and loafing area



Covering the metal bars above the feeding troughs were clear Perspex sheets. These dividers prevented the donkeys from sharing food with neighbouring animals. Rubber matting covered by none edible bedding (Easibed, GI Hadfield & Sons Ltd, Manchester, UK) provided comfortable flooring in the stables and encouraged the donkeys to rest. During intake recording and faecal collection phases the bedding was removed to aid the collection of food refusals and faecal deposits and reduce sample contamination with bedding material.

Loafing and Yard Area

An indoor loafing area and outside yard were provided to enable the donkeys to socialise and exercise themselves. An area of none edible bedding (Easibed) in the loafing area provided a place for the donkeys to roll and rest. The wooden fence bordering the yard was covered by plastic mesh netting to prevent wood chewing and access to any vegetation. During intake recording and faecal collection phases the donkeys were allowed into these areas between feeding times. When undertaking total faecal collection the donkeys were under constant observation for any faecal deposits. During rest periods the donkeys were housed and managed as one group in these areas and fed using large metal livestock feeders.

4.2.4 Management and Diet

Routine

The daily routine followed during each phase is shown in Table 4.1. During intake recording and faecal collection phases the donkeys were removed from their stables into the loafing area before meal 1 to facilitate sample collection and allow each stable to be thoroughly cleaned. The donkeys were removed from their stables in small groups (6 - 8 donkeys) to reduce the time taken to collect refusals and faeces from the empty stables. Removing the donkeys from their stables in small groups reduced the time each group was out of the stables, reducing the time each donkey was prevented from eating due to the collection of refusals and faecal deposits. Each group was out of their stables for approximately 1 hour and 15 minutes for this reason. On returning to their stables each donkey received meal 1.

Donkey body weights were monitored daily for the duration of the study (11:00h) using a weigh bridge (Horseweigh, Powys, Wales, UK). Rations were adjusted accordingly to maintain the donkeys at a stable body weight (± 5kg of start weight).

Table 4.1. Management routine followed during equilibrium and sample collection phases

Phase	Equilibrium Phase	
Time	**Activity**	**Area**
07:00h	Donkeys let out of stables into loafing/yard area Stables cleaned of food refusals, faeces and urine	Loafing/yard
09:30h	Donkeys put back into stables and receive meal 1	Stable
11:00h	Donkeys weighed, then into loafing/yard area Grooming and routine treatments	Loafing/yard
13:00h	Donkeys return to stables, receive meal 2	Stable
14:30h	Donkeys let out of stables Stables cleaned of faeces or urine Food weighed for following day	Loafing/yard
19:00h	Donkeys let into stable Donkeys receive meal 3	Stable
	Intake and Faecal Collection Phase	
05:30h	Donkeys let out of stables in small groups * Collection of refusal and faecal samples Donkeys received meal 1 on returning to their stables	Loafing/yard
10:30 – 11:00h	Donkeys walked in hand in groups of 6-8, 10 minutes each group	Track
11:00h onwards	Same as Equilibrium phase	

* Donkeys were observed to ensure no faeces were lost

Feeding and Diet

Throughout the experiment the donkeys received a diet of hay and barley straw, and had access to pasture during the summer rest periods. The donkeys received their daily ration in 3 meals; 25% in meals and 1 and 2, remaining 50% in meal 3. Each days ration was weighed on the previous day using a Cardinal Weigh Scale and stored in plastic dustbins with secure lids. Rations were calculated as percentage body weight on a DM basis. The donkeys received rations equivalent to 1.50 - 1.75, 2.48 and 2.00% body weight, at hay:straw ratio of 25:75, 70:30 and 50:50, for Periods 1 and 2, 3, and 4, respectively. (Individual rations in Appendix 4).

4.2.5 Sample Collection

During the intake recording and faecal collection phases the 24 hour day ran from 09:30h on day 1 to 09:30h the following day. This 24 hour routine continued until the end of each recording period. Regular collections of any wet refusals and faecal deposits were carried out throughout each 24 hour period, and stored in the appropriate donkeys storage bags (each donkey had 3 bags; 1 for faecal deposits; 1 for wet food refusals; 1 for dry food refusals). At the end of each 24 hour period but prior to the feeding of meal 1 of the next 24 hour day, a final collection of all refusals (wet and dry) and faecal deposits was made for each donkey and all stables cleaned thoroughly (Plate 4.1).

Plate 4.1. Separation of faeces and wet and dry refusals prior to collection

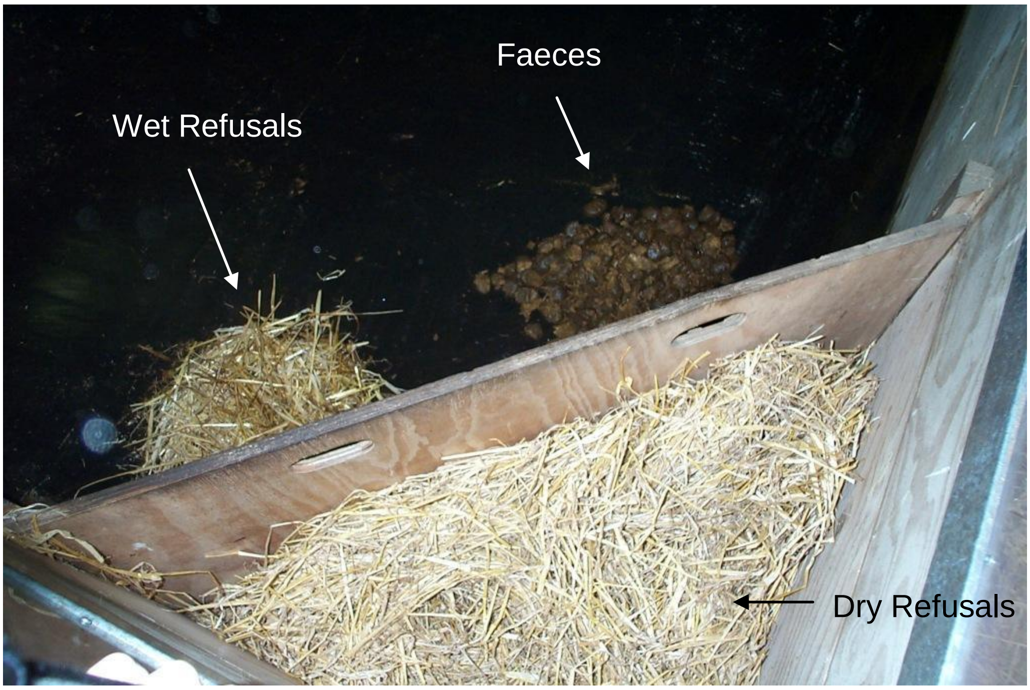


Plate 4.2. Weighing and recording of refusal fresh weight

Food Offered

Samples of the food offered during the intake recording and faecal collection phases were taken. Grab samples were taken from the centre of each new hay and straw bale opened and stored in individual airtight bags. At the end of each recording period, for each forage, the grab samples were mixed together in a clean bucket and a subsample taken. Each subsample was chopped into approximately 5cm long pieces and two further subsamples taken. One sample was placed into a metal tray and dried at 100^{o}C in a force draft oven to a constant weight. The second subsample was dried at 60^{o}C until a constant weight and retained in an airtight bag for nutritional analysis. Drying the second sample at a lower temperature reduced the amount of loss of volatile organic acids, alcohols and ammonia incurred with oven drying samples (Van Soest & Robertson, 1985).

Food Refusals

Wet and dry food refusals were collected separately into individually labelled plastic bags during the intake recording and faecal collection phases. The fresh weight of each donkey's daily wet and dry refusals were measured and recorded (Plate 4.2). A sample of each wet and dry refusal was taken, chopped into approximately 5cm long pieces and dried as for food offered to determine DM content using the method described above.

Faecal Collection

The fresh weight of each donkey's total daily faecal output were measured and recorded. For each donkey, each day, two grab samples were taken. One sample was dried as for food offered to determine DM content. The second sample was stored in a freezer until the end of each recording period. On completion of each recording period all the frozen faecal samples for each donkey were defrosted, and according to the percentage contribution the daily faecal output made to the total faecal collection over 5 days, proportionally pooled to form a 250g sample. The samples were dried at 60^{o}C in a force draft oven until at constant weight and retained for nutritional analysis.

4.2.6 Nutritional Analysis

Prior to nutritional analysis all dried faecal and food offered samples were ground using a hammer mill through a 1mm screen.

Food offered and faecal samples were analysed for their nutrient content according to the methods reported by the Association of Official Analytic Chemists (1990). Samples were analysed for ash, CP, GE, NDF and ADF. The residual DM (rDM) content of samples was also measured to account for the hygroscopic nature of ground samples. *In vitro* DM digestibility was analysed using the NCGD technique developed by Ankom Technology (Ankom, 2006) (See 3.2.5, Food Sample Analysis).

4.2.7 Calculations

Dry matter and nutrient intakes were calculated using equation 4.1. Apparent digestibilities were calculated using equation 4.2. Endogenous nitrogen (N) losses (including microbial protein) were accounted for using equation 4.3 and the results subtracted from CP faecal output values.

Equation 4.1.

$$\text{Intake} = \text{amount offered} - \text{amount refused}$$

Equation 4.2.

$$\text{Apparent digestibility} = \frac{\text{nutrient intake} - \text{faecal output}}{\text{nutrient intake}}$$

Equation 4.3.

$$\text{Endogenous N losses (g/day)} = (52\text{mg x BW}^{0.75}) \text{ x } 6.25$$

(Prior *et al*., 1974)

4.2.8 Statistical Analysis

Data was checked for normality of distribution and similarity of variance between treatments (season and sex) using the Anderson-Darling and Levene tests, respectively. All data was normally distributed therefore the mean and standard error were calculated.

Removal of unhealthy donkeys resulted in unbalanced experiments therefore differences in requirements between seasons and sexes were tested using the general linear model two way analysis of variance (ANOVA). Specific differences between treatments were identified using the Tukey test. General linear regression was used to assess body weight change during each season and the relationship between DEI and body weight. All statistical analysis was carried out using Minitab 15 (Minitab Ltd, Coventry, UK).

4.3 RESULTS

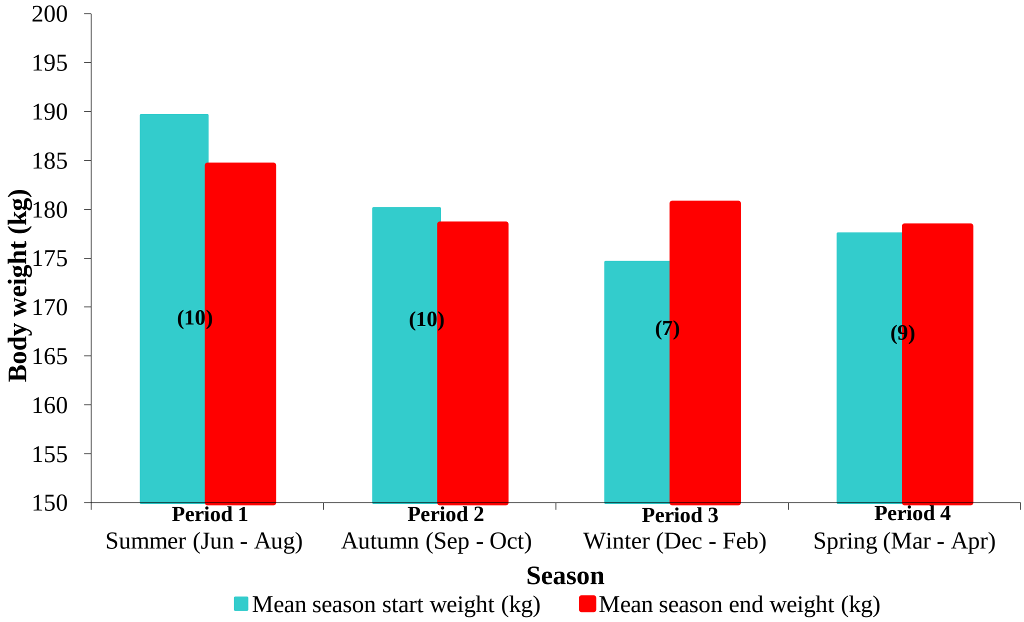
4.3.1 Body Weight

Mean body weight changes during the equilibrium, intake recording and total faecal collection phases of each season are shown in Figure 4.3. The aim of the experiment was to calculate energy requirements for maintenance, therefore it was imperative that donkeys maintained a near constant weight for the duration of the study. Daily fluctuations in weight due to gut fill, or defecation, were accounted for by a 5kg margin of error. Any daily change in body weight within the 5kg margin was attributed to normal variation in weight. Consistent increases or decreases in weight over time (experimental days) were attributed to changes in fat deposition due to either a surplus or shortage in energy intake, from which it could be concluded that donkeys were not eating for maintenance.

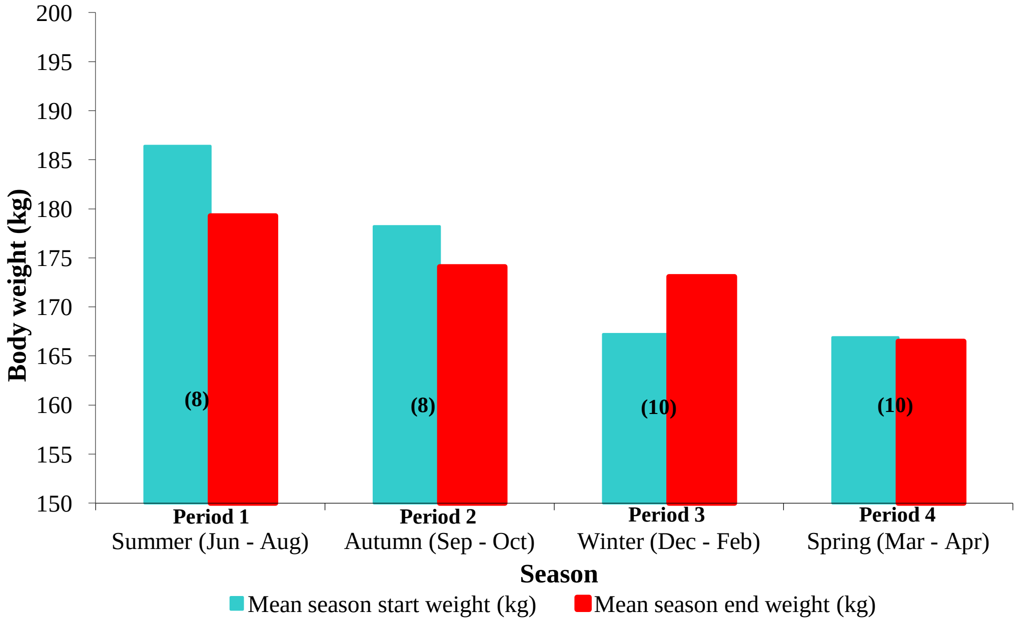
Maintenance of body weight was not achieved for all females during summer and geldings and females during winter. Small losses in weight were incurred in summer and autumn resulting in average total losses for geldings and females of 4.8 and 7.1kg respectively during summer and 1.6 and 4.6kg respectively during autumn (Figure 4.3). However, regression analysis of body weight versus experiment day for geldings and females during each season found no relationships between body weight and experimental periods (Appendix 5). Start and end body weights from each season were also statistically similar ($P>0.05$). Increases in weight during winter (6.1 and 5.9kg, geldings and females, respectively) can be attributed to significantly higher DM and DE intakes ($P<0.001$) in this period as a result of an increased hay proportion in the ration (Table 4.3). Body weights during spring were constant in both geldings and females, with less than a kilogram change between average weight at the start and end of the recording period.

Figure 4.3. Mean start and end body weights of donkeys during each season.
Numbers in parenthesis represent number of donkeys each period.

(a) Geldings



(b) Females



4.3.2 Diet and Ration Composition

Diet composition and published values for grass hay and barley straw are shown in Table 4.2. Crude protein, NDF, ADF and DMD fractions were significantly higher in the hay compared to the straw when data from all seasons was combined. The hays fed in autumn and winter were similar in nutrient value for all fractions, having lower CP, NDF and ADF content than hays fed in summer and spring. The low OM content of the spring ration, combined with the highest CP content, produced the highest DMD result. Organic matter, DM and NDF content of the straws fed each season showed little variation. However, the statistically lower ADF content of the winter straw resulted in the highest DMD result, compared to *in vitro* digestibility results for straws in all other seasons.

Comparison of results with published values for hay show lower CP levels for all seasons, indicating poor quality hays were fed. Low NDF and ADF levels in the autumn and winter hays (NDF range 648 – 652g/kg DM, ADF range 377 – 392g/kg DM), however, suggest average to good quality hays were fed. The low cell wall content combined with the low CP levels may be due to losses of soluble nutrients incurred during forage processing or storage.

The CP levels of the straws fed each season were similar to published values for barley straw except during summer, when CP content was equivalent to that of the summer hay, and exceeded the protein content of the hays fed in autumn and winter and published values. The straw fed in spring was of particularly poor quality, with the highest NDF and ADF content of all straws fed. However, all straws fed during the study contained higher NDF and ADF levels compared to published values for barley straw.

Table 4.2. Ration composition and nutrient content of diets offered during each season (g/kg DM unless otherwise stated). Where two samples were analysed per forage per season the mean ± s.e. are reported (*n*: number of analysed samples per season)

Forage	*Dif.*	Nutrient Fraction (*n*)	Season: Period 1 Summer (Jun – Aug)	Season: Period 2 Autumn (Sep – Oct)	Season: Period 3 Winter (Dec – Feb)	Season: Period 4 Spring (Mar – Apr)	Published Values (McDonald *et al.*, 2002): Good Quality	Published Values (McDonald *et al.*, 2002): Poor Quality
Hay		**DM (g/kg) (1)**	921	903	902	913	900	800
		GE (MJ/kg DM) (1)	15.5	14.9	14.9	14.3	-	-
		OM (1)	964	991	972	954	918	930
	**	**CP (2)**	53 ± 2.9 a,b	45 ± 4.4 a,b	44 ± 4.1 b	64 ± 1.3 a	110	55
	***	**NDF (2)**	689 ± 3.3 A	652 ± 3.8 B	648 ± 2.9 B	689 ± 6.9 A	650	741
	***	**ADF (2)**	411 ± 11	392 ± 1.7	377 ± 16.3	413 ± 1.5	364	452
	***	**† *In vitro* DMD (%) (2)**	40 ± 0.9 A	41 ± 0.2 A	48 ± 0.2 B	52 ± 1.2 B		
Straw		**DM (g/kg) (1)**	925	924	919	929	860	
		GE (MJ/kg DM) (1)	16.1	15.9	15.3	15.3	-	
		OM (1)	979	973	979	973	947	
	**	**CP (2)**	52 ± 1.8 a	38 ± 0.4 a,b	33 ± 4.8 b	29 ± 1.3 b	38	
	***	**NDF (2)**	855 ± 1.9	861 ± 2.3	849 ± 1.7	868 ± 8.6	811	
	***	**ADF (2)**	570 ± 12.6 a,b	590 ± 7.0 a,b	544 ± 4.4 b	609 ± 1.5 a	509	
	***	**† *In vitro* DMD (%) (2)**	32 ± 0.8 a,b	30 ± 1.4 a	39 ± 1.6 b	33 ± 1.4 a,b		
% Straw in ration			75	75	30	50		
% Hay in ration			25	25	70	50		
Estimated ration DMD (*in vitro*) (%)			39	38	42	43		
Estimated ration DE content (MJ/kg DM)			6.9	6.0	6.7	6.2		

Dif: Significance of difference between nutrient content of forages, analysed for each nutrient fraction (using data from all seasons) * P<0.05, ** P<0.01, P<0.001

† *In vitro* dry matter digestibility determined via NCGD analysis (neutral cellulase plus gamanase)

a, b,c: Means on the same row bearing different letters differ significantly (P<0.05). Rows containing no letters were statically similar.

A, B: Means on the same row bearing different letters differ significantly (P<0.01)

The winter ration would be expected to have the highest DE content due to the higher hay content, and greater digestibility of the hay and straw fed in this season, compared to that fed in summer and autumn (Table 4.2). However, the summer ration was the most energy dense, despite a 75:25 straw:hay ratio, due to the high energy content of both the hay and straw fed during this period. The lower energy content of the hay fed in autumn compared to that fed in summer, combined with the lowest *in vitro* DMD results for both forage types, and the high straw content, produced the least energy dense ration in autumn.

4.3.3 Diet Digestibility

Apparent digestibility of each nutrient fraction is shown in Table 4.3. Changes in the straw:hay ratio offered during each season resulted in significant differences in apparent digestibilities ($P<0.001$). Increasing the hay content of the winter ration increased the digestibility of DM, but had no affect on OM, GE and CP digestibility. The high hay content of the winter ration also produced the lowest NDF and ADF digestibilities, although NDF digestibility was similar to that on the high straw autumn ration. The apparent digestibilities of all nutrient fractions, except ADF, were similar in the spring and summer seasons despite differences in the straw:hay ratio. The combined effect of a high ADF content in the straw fed in autumn, and a high straw content in the ration resulted in the lowest OM, GE and CP digestibilities in autumn ($P<0.001$).

Table 4.3. *In vivo* apparent digestibility coefficients (± s.e.) of diets by donkeys during each season based on 5 day total collection (See 4.2.1 and Figure 4.1)

		Season								Significance of effect of	
		Period 1 Summer (Jun – Aug)	s.e.	**Period 2 Autumn (Sep – Oct)**	s.e.	**Period 3 Winter (Dec – Feb)**	s.e.	**Period 4 Spring (Mar – Apr)**	s.e.	**sex**	**season**
No. of Animals	**Geldings**	10		10		7		9			
	Females	8		8		10		10			
Apparent Digestibility											
DM	**Geldings**	0.47 a,b	0.013	0.42 a	0.008	0.50 c	0.014	0.49 b,c	0.022	NS	***
	Females	0.46 a,b	0.024	0.44 a	0.014	0.54 c	0.014	0.51 b,c	0.017		
OM	**Geldings**	0.50 a	0.014	0.45 b	0.008	0.51 a	0.012	0.52 a	0.018	NS	***
	Females	0.49 a	0.016	0.47 b	0.008	0.55 a	0.017	0.54 a	0.014		
GE	**Geldings**	0.43 a	0.018	0.37 b	0.015	0.42 a	0.014	0.41 a	0.022	NS	***
	Females	0.43 a	0.019	0.39 b	0.004	0.46 a	0.020	0.43 a	0.015		
CP	**Geldings**	0.36 a	0.030	0.18 b	0.041	0.35 a	0.021	0.36 a	0.034	NS	***
	Females	0.32 a	0.038	0.17 b	0.023	0.46 a	0.050	0.37 a	0.026		
NDF	**Geldings**	0.56 a	0.014	0.50 b	0.006	0.45 b	0.015	0.56 a	0.018	NS	***
	Females	0.55 a	0.016	0.52 b	0.010	0.50 b	0.017	0.58 a	0.014		
ADF	**Geldings**	0.53 a	0.016	0.53 a	0.007	0.44 b	0.023	0.60 c	0.017	NS	***
	Females	0.53 a	0.018	0.56 a	0.011	0.49 b	0.016	0.61 c	0.013		

a, b, c: Means on the same row bearing different letters differ significantly
NS: not significant, *** P<0.001

Table 4.4. Mean (± s.e.) daily dry matter (DM), digestible energy (DE) and digestible crude protein (DCP) intakes by donkeys each season based on measurements over 12 days (See 4.2.5 and Figure 4.1)

		Season								Significance of effect of	
		Period 1 Summer (Jun – Aug)	s.e.	Period 2 Autumn (Sep – Oct)	s.e.	Period 3 Winter (Dec – Feb)	s.e.	Period 4 Spring (Mar – Apr)	s.e.	sex	season
No. of Animals	Geldings	10		10		7		9			
	Females	8		8		10		10			
Intakes											
DM (kg/day)	Geldings	2.40 a	0.036	2.47 a,b	0.040	3.30 c	0.142	2.76 b	0.044	NS	***
	Females	2.23 a	0.044	2.39 a,b	0.037	2.97 c	0.154	2.57 b	0.040		
DM (g/kg $BW^{0.75}$)	Geldings	48 a	1.0	51 a,b	2.0	69 c	4.0	56 b	2.0	NS	***
	Females	45 a	2.0	50 a,b	2.0	63 c	3.0	55 b	2.0		
DE (MJ/day)	Males	16.8 a	0.96	14.5 a	0.97	21.0 b	1.06	16.0 a	0.71	NS	***
	Females	15.2 a	1.27	14.6 a	0.70	20.0 b	1.35	15.6 a	0.61		
DE (MJ/kg $BW^{0.75}$)	Geldings	0.33 a	0.014	0.30 a	0.017	0.44 b	0.027	0.33 a	0.017	NS	***
	Females	0.31 a	0.027	0.30 a	0.014	0.42 b	0.024	0.34 a	0.018		
DCP (g/day)	Geldings	42.3 a	3.50	17.2 b	3.55	45.1 c	3.48	45.0 a,c	3.52	NS	***
	Females	33.6 a	4.11	15.0 b	2.07	53.5 c	7.24	44.9 a,c	3.21		

a, b, c, d: Means on the same row bearing different letters differ significantly
NS: not significant, *** P<0.001

4.3.4 Food Intake

Mean daily DMI during each season is shown in Table 4.4. All animals had food refusals every day during each season. Refusals averaged 21, 16, 28 and 24% of daily DM offered during summer, autumn, winter and spring, respectively. Donkeys showed a strong preference for hay as all refusals invariably consisted of straw. The combination of food refusals, and the relatively stable body weights of donkeys, shows that voluntary food intake was attained and the donkeys were eating for maintenance.

Season had a significant effect on DM, DE and DCP intakes ($P<0.001$). Dry matter intake was similar in summer and autumn and autumn and spring but significantly higher in winter than all other seasons ($P<0.001$). The lowest DMI (g/kg $BW^{0.75}$) were in summer, however, the lowest DE (MJ/kg $BW^{0.75}$) and DCP (g/day) intakes were in autumn. The ability to gain more energy and protein from a lower DMI reflects the higher energy density and CP content of the summer ration. The lower DE and DCP intakes in autumn were due to significantly ($P<0.001$) lower GE and CP digestibilities, resulting in the donkeys gaining less energy and protein per unit of food consumed. Maintenance of body weight during winter required feeding a higher proportion of hay in the ration. This higher hay ratio increased digestibility and energy density of the winter ration compared to that fed in autumn, increasing DM and DE intakes significantly ($P<0.001$). Female donkeys generally had lower intakes than male donkeys when results were expressed as total daily intake. However, when expressed on a body weight basis this difference was reduced.

Figure 4.4 shows the result of regression analysis of body weight and DEI by all donkeys during all seasons. Digestible energy intake (MJ/day) versus body weight showed a weak but significant relationship (DEI (MJ/day) = 2.25 + 0.081 BW (kg), r^2 = 20%, P<0.001) (Figure 4.4). Comparison of DEI and body weight per season found stronger relationships in the summer and winter data compared to that for autumn and spring (Figure 4.5). Summer DEI (MJ/day) versus body weight (kg) = -7.32 + 0.13 BW, r^2 = 58%, P<0.001. Winter DEI versus body weight (kg) = 0.11 + 0.12 BW, r^2 = 45%, P<0.01. To account for the stronger association between energy intake and body weight when winter data were tested separately, and the similar DEI by donkeys in summer, autumn and spring (16.1, 14.6 and 15.8MJ/day respectively, Table 4.4), DEI for summer, autumn and spring combined were regressed against corresponding body weights. Analysis found a stronger relationship between DEI and body weight when using these three seasons (DEI (MJ/day) = 1.96 + 0.077 BW (kg), r^2 = 31%, P<0.001) (Figure 4.6), compared to when using data from all four seasons. The use of metabolic body weight in the regression analysis produced similar results as using body weight for all four seasons, indicating there was no benefit in using metabolic body weight when estimating energy requirements for these donkeys.

Figure 4.4. Regression analysis of digestible energy intake (DEI MJ/day) versus body weight (BW kg) for all donkeys during all seasons
(DEI (MJ/day) = 2.25 + 0.081 BW (kg), r^2 = 20%, P<0.001)

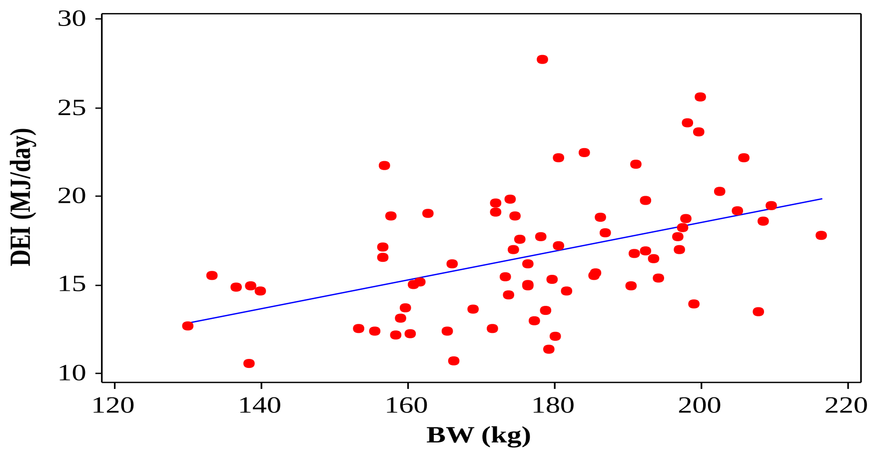


Figure 4.5. Regression analysis of digestible energy intake (DEI MJ/day) versus body weight (BW kg) by donkeys during summer, autumn, winter and spring

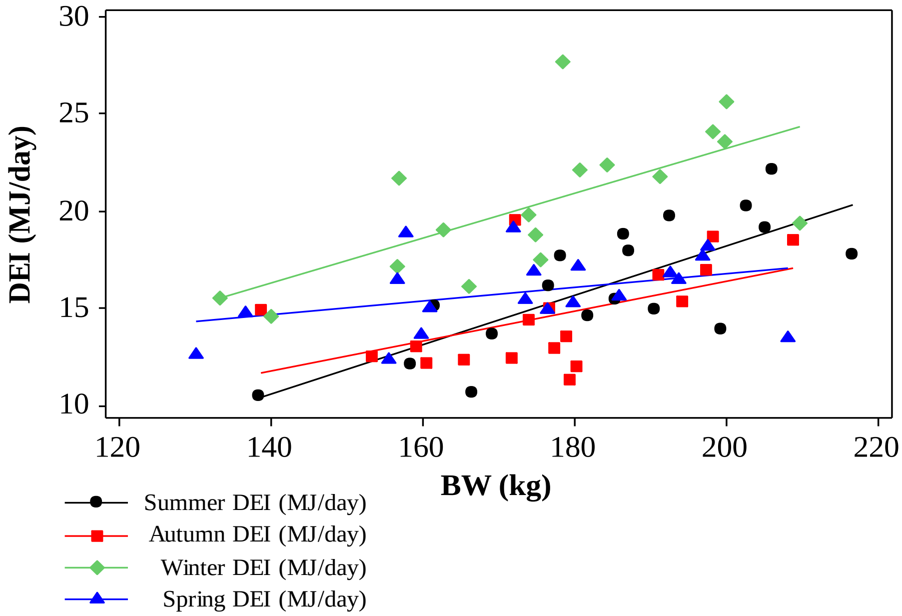
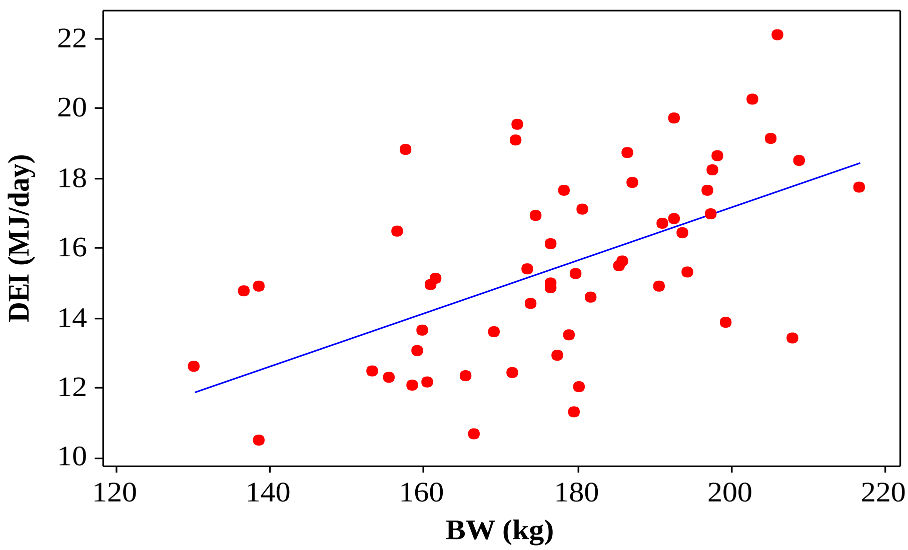


Figure 4.6. Regression analysis of combined data of digestible energy intake (DEI MJ/day) versus body weight (BW kg) by donkeys during summer, autumn and spring
(DEI (MJ/day) = 1.96 + 0.077 BW [kg], r^2 = 31%, P<0.001)



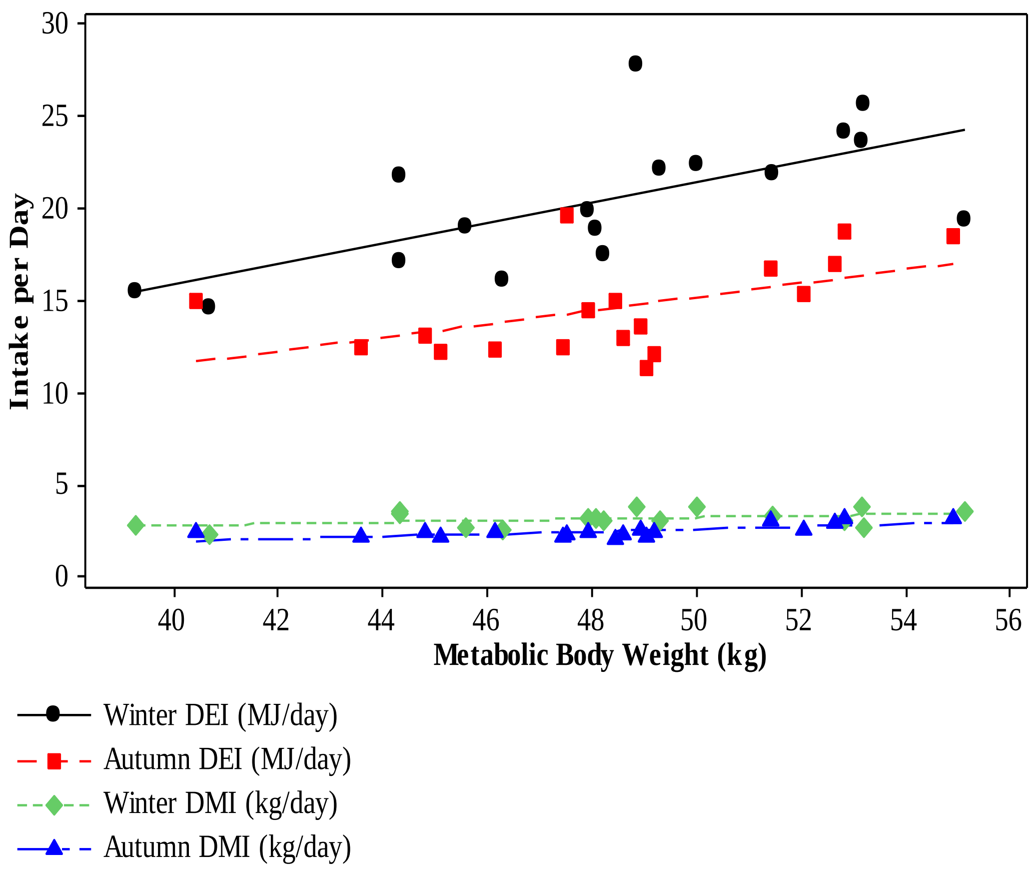
4.3.5 Seasonal Change in Food Intake

Seasonal changes in DM, DE and DCP intakes are shown in Figure 4.8. If ration composition had remained the same throughout the study, fluctuations in DMI would have resulted in similar proportional fluctuations in DE and DCP intakes. Variations in ration composition between seasons, however, resulted in different proportional fluctuations in DM, DE and DCP intakes between seasons.

The quality of the diet in autumn was lower than that fed in summer. In response to receiving this poorer quality diet, DMI, expressed as a proportion of metabolic body weight, increased on average by 8% for geldings, and 12% for female donkeys, from summer to autumn. Despite the increase in food intake to compensate for the lower quality diet, DEI from summer to autumn decreased by 10% in geldings, and increased by only 2% in females. The lower DEI's are reflected by a loss of body weight between these two seasons. Body weights at the start (Figure 4.3) and during (Figure 4.7) autumn were lower than those at the start and during summer. During the same period DCP intakes also decreased by more than 50% in all donkeys.

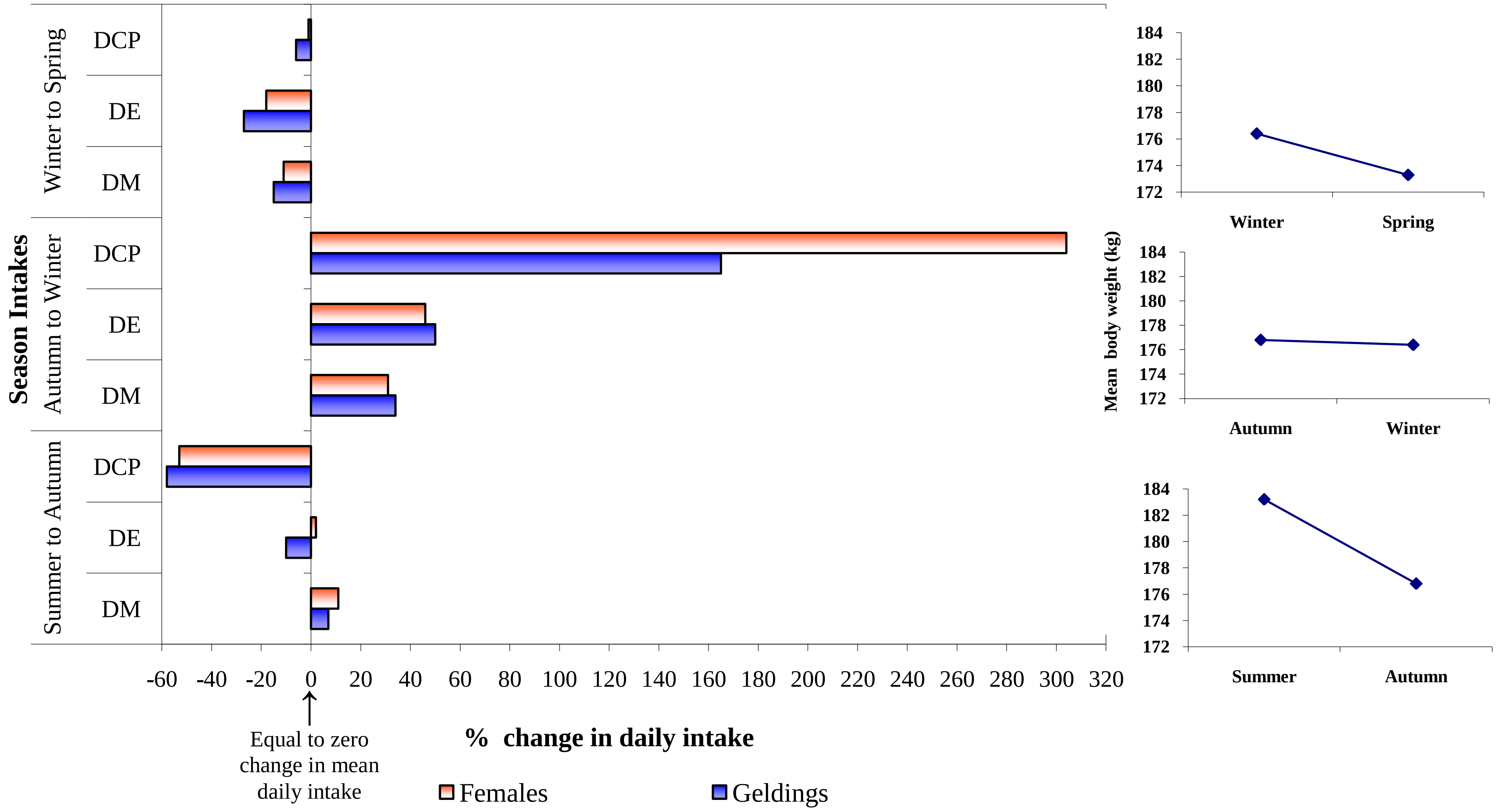
Digestible energy intakes, on a metabolic body weight basis, increased by approximately 50% in all donkeys from autumn to winter (Figures 4.7 and 4.8). If energy requirements had remained the same during both these seasons then food intake would decrease to account for the higher energy density of the winter ration, or body weight would increase due to excess energy intakes. Only a slight increase in body weight during winter (Figure 4.3) indicates energy intakes were in balance with energy requirements, and maintenance energy requirements of donkeys in winter increase by approximately 50%. Dry matter intake in winter did increase by on average 31% in all donkeys, showing, that although the donkeys ate more food, the higher energy content of the winter ration required a smaller increase in food intake (Figure 4.7). Digestible crude protein intakes showed the greatest increase between autumn and winter, although this result is severely affected by the significantly lower DCP intakes in autumn. However, comparison between DCP intakes during summer and winter also show increases of 15 and 85% for geldings and females in winter, respectively. The higher hay content of the winter ration, combined with similar CP digestibility during summer and winter, resulted in donkeys gaining more DCP per unit of winter ration consumed.

Figure 4.7. Digestible energy intake (DEI MJ/day) and dry matter intake (DMI g/kg) by donkeys in autumn and winter



In spring the donkeys ate less than during winter with DMI decreasing by 15 and 11% in geldings and female donkeys, respectively. These lower intakes, combined with the lower energy density of the spring ration, resulted in lower DEI. Body weight during spring remained stable, being within 3kg of body weights during winter, confirming that the higher energy intakes in winter were due to increased energy requirements. Changes in DCP intake were minimal due to the high CP content of the hay fed in spring (-6% in geldings, -1% in females).

Figure 4.8. Seasonal changes in body weight and daily dry matter (DM) (g/kg $BW^{0.75}$), digestible energy (DE) (MJ/kg $BW^{0.75}$) and digestible crude protein (DCP) (g/day) intakes by geldings and female donkeys



4.4 DISCUSSION

4.4.1 Body Weight

The aim of the study was to determine nutrient requirements of donkeys for maintenance. Body weights at the start and end of each season were statistically similar indicating that this requirement was achieved. Losses in body weight were within the 5kg error margin, excluding females in summer. Despite this fluctuation in body weight, it is concluded that donkeys were eating to near maintenance due to the similarity in mean weights at the start and end of each season.

4.4.2 Diet and Ration Composition

Donkeys showed preference for the hay, as indicated by them eating all the hay before eating any of the straw. This preference reflects the greater palatability of the hay (Dulphy *et al*., 1997b), and may indicate greater ease with which hay is eaten compared to straw (Smith, 1999), due to a lower fibre content. Comparison of forage composition with published values (McDonald *et al*., 2002) show the diets fed were not good quality. Hays fed in all seasons were of average to poor quality due to low CP levels (hays 44 – 64g/kg DM, published value for good quality hay 110g/kg DM). The high cell wall content of the hays fed in summer and spring (689g/kg DM) also suggests poorer quality hays were fed during these seasons, although *in vitro* digestibility results were highest for the spring hay.

Results from this study show that mature, healthy donkeys can satisfy maintenance energy demands from relatively poor quality diets even in the colder winter months, and that concentrate feeds are not required to satisfy energy demands. Rations containing a minimum of 50% straw enabled donkeys to satisfy appetite without consuming excess energy during summer, autumn and spring. During winter the increase in energy demand required the proportion of hay in the ration to be increased. Although DMI increased during winter, the increase in energy demand from autumn to winter was greater than that in food intake (DEI increase 50%, DMI increase 31%), thus a higher energy ration was needed. Increasing the hay ratio in the winter ration to 70% increased ration DE, producing a more energy dense ration than that offered in autumn. Increasing the hay ratio probably also increased intake rate due to shorter chewing time, enabling donkeys to consume more food.

4.4.3 Diet Digestibility

Apparent digestibility results reflect changes in ration and diet composition with the changes in fibre content seeming to have the greatest influence. The effect of diet and intake on digestive coefficients is also evident from previous results for donkeys fed all forage diets. Apparent DMD coefficients of straw based diets by donkeys range from 0.47 - 0.56, and are lower than those of grass hay or dehydrated alfalfa based diets (0.51 - 0.63) (Butterworth *et al*., 1987; Tisserand *et al*., 1990; Pearson & Merritt, 1991; Cuddeford *et al*., 1995; Pearson *et al*., 2001). Dry matter digestibility coefficients of the straw and hay based diets fed in this study in summer (0.47) and winter (0.52) are within these ranges, indicating that the donkeys in this study digested forage diets to a similar extent to previous reports for donkeys.

The effect of DMI on NDF and ADF digestibility seen here is also evident from previous studies comparing DMI and apparent digestibility of different forages by donkeys. Cuddeford *et al*. (1995) fed donkeys a combination of dehydrated alfalfa and molassed oat straw to estimated energy requirements in quantities similar to the hay:straw ratio fed here in summer and winter, and found that NDF and ADF apparent digestibility of the alfalfa based diet was higher than that of the straw based diet, partly due to a lower DMI. The lower energy value of the straw diet, compared to that of the alfalfa diet, required higher DMI resulting in a faster passage rate of digesta through the GIT (Cuddeford *et al*., 1995).

Forage type has an opposite effect when feeding *ad libitum*. Pearson and Merritt (1991) and Pearson *et al*. (2001) both report higher DMI but lower NDF and ADF digestive coefficients by donkeys eating hay, compared to when eating straw. In both studies, the passage rate of digesta through the GIT was faster on the hay diet. Donkeys were not fed *ad libitum* in this study although the presence of food refusals show DMI was not restricted by the amount of food offered, and resulted in the same effect of DMI on NDF and ADF digestibility as that seen in donkeys fed *ad libitum*. During summer, when receiving the straw based diet, donkeys consumed less food but digested NDF and ADF to a greater extent compared to when receiving the hay based diet in winter. So although donkeys select for a better quality diet when available, they are able to efficiently utilise poor quality diets by increasing the amount of energy derived from microbial fermentation. These results combined with those of *ad libitum* fed donkeys (Pearson & Merritt, 1991; Pearson *et al*., 2001), oppose the theory that when offered foods of low quality, equids increase their DMI to maintain intake of soluble nutrients, but at the consequence of microbial fermentation (Janis, 1976). Donkeys appear to increase the utilisation of cell wall fractions when offered fibrous forages whilst maintaining low food intakes.

4.4.4 Food Intake

Donkeys offered all forage diets have been reported to consume between 37 and 100g DM/kg $BW^{0.75}$. The lower end of this range is comprised from the DMI of straw based diets (37 – 77g DM/kg $BW^{0.75}$) and the higher end of this range (67 – 100g DM/kg $BW^{0.75}$) from the intake of grass and legume hays (Butterworth *et al*., 1987; Tisserand *et al*., 1990; Pearson & Merritt, 1991; Mueller *et al*., 1994; Nengomasha *et al*., 1999; Pearson *et al*., 2001). Dry matter intakes of the high straw rations by donkeys in this study during summer and autumn were similar to those reported previously for donkeys consuming straw (Table 4.4). Dry matter intakes of the hay based rations fed in this study during winter (66g DM/kg $BW^{0.75}$, Table 4.4) were lower than previously reported for donkeys consuming hay, but similar to those reported by Mueller *et al*. (1994) (67g DM/kg $BW^{0.75}$) for maintaining donkeys at a constant weight when receiving a grass hay diet. Digestible energy intakes by donkeys in the present study, however, were lower during all seasons than that reported by Mueller *et al*. (1994) for the maintenance of body weight (0.51MJ DE/kg $BW^{0.75}$).

Differences in environmental temperature between the present study and that by Mueller *et al*. (1994) do not account for differences in maintenance energy requirements. Both studies were carried out in temperate climates, with temperatures inside the experimental barns ranging from 6 – 10^{o}C in this study and 10 – 21^{o}C in the published study. Management routines in both studies were also similar, with donkeys having approximately 6 hours daily access to an exercise/socialising area. It is probable that the donkeys in the study by Mueller *et al*. (1994) were consuming energy in excess of their requirements, but that the short duration of the 4 week study was not long enough to record any significant increases in body weight. After an initial loss of body weight, the donkeys were gaining weight during the second week of intake recording.

Results from the first long term study into the maintenance DE requirements of donkeys, undertaken in Mexico, reported mean DEI of 0.32, 0.45, 0.40 and 0.51MJ DE/kg $BW^{0.75}$ for summer, autumn, winter and spring, respectively, when offering a ration of chopped straw and alfalfa hay (ratio 85:15) (Carretero-Roque *et al*., 2005). Maintenance DE requirements of the donkeys in the present study were the same as those of the Mexican donkeys in summer (0.32MJ DE/kg $BW^{0.75}$), but slightly higher in winter (0.43MJ DE/kg $BW^{0.75}$). The similar energy requirements in summer reflect similarities in climate between the two study sites. Mean ambient temperatures in Toluca, Mexico, range from 6 – 25^{o}C during summer, comparable to those in Devon (13 – 21^{o}C). The higher DE requirements of the donkeys in the UK in winter may be a result of a higher energy demand for maintaining body temperature in the slightly colder winter climate of the UK (mean winter ambient temperature: UK 4.6^{o}C, Mexico 9^{o}C). In addition to colder temperatures, winters in the UK have high rainfall compared to the dry winters in Toluca. The combination of the damp and cold environment of this study may therefore have further increased energy requirements for maintenance. The higher DEI in spring in the Mexican study is attributed to a higher energy content and GE digestibility of the ration offered. Despite these slight differences in DE requirements for maintenance between the two studies, the results reported by Carretero-Roque *et al*. (2005) support the results gained from this study.

Regression analysis was carried out to determine if body weight could be used to estimate DE requirements in these donkeys. The strongest relationships were found when seasons were analysed separately, with summer and winter body weight being the most accurate predictors of DEI. The finding that DEI's were more closely related to body weight when seasons were analysed separately clearly shows the difference in energy intake between seasons, with DEI's being the highest in winter. Accounting for the higher DEI's in winter, the relationship between body weight and energy intake was tested excluding the winter data (Figure 4.6). The relationship between energy intake and body weight using all seasons except winter was weaker (DEI (MJ/day) = 1.96 + 0.076 BW (kg), r^2 = 31%, P<0.001) than that calculated using only the summer data (DEI (MJ/day) = -7.32 + 0.128 BW (kg), r^2 = 58%, P<0.001). The summer data would therefore be the best predictor of DEI by donkeys in summer, autumn and spring, with the equation derived from the winter data being the most suitable for predicting winter DE requirements of these donkeys. Further research is needed to determine if the DEI's by the donkeys studies here are representative of other donkeys before these regression models can be used to estimate the DE requirements of the general UK donkey population.

Digestible crude protein intakes by donkeys fed all forage diets vary considerably, with Pearson and Merritt (1991) reporting donkeys in negative protein balance when fed a diet of barley straw *ad libitum*, and Pearson *et al*. (2001) reporting a daily DCP intake of 374g by donkeys on a diet of dehydrated alfalfa. Digestible crude protein intakes in the present study ranged from 16.4g/day on the straw based ration to 51.3g/day on the hay based ration. Protein deficiency in the mature horse can reduce DMI, hoof growth and coat hair quality (NRC, 1989), although none of these symptoms were exhibited by the study donkeys. The absence of any signs of protein deficiency in donkeys receiving low protein rations in this and previous studies, may be due to a lower urinary nitrogen excretion rate when fed diets of low protein content, leading to an increased ability to retain nitrogen within the body with the effect of reducing dietary nitrogen requirements (Izraely *et al*., 1989a,b).

4.4.5 Seasonal Change in Food Intake

Seasonal variation in DM and DE requirements in equids in the UK has not previously been investigated. The effect of specific temperature extremes (-40^{o}C and 40^{o}C) on DEI by donkeys and horses have been investigated (McBride *et al*., 1985; Yousef, 1985), however, the effect of the temperature fluctuations of the UK climate have not. General assumptions are that DE requirements increase as animals are exposed to high and low environmental temperatures (Cymbaluk, 1994; Robbins, 2001), although by how much these energy demands increase, and at what temperature ranges, requires further investigation. Carretero-Roque *et al*. (2005), reporting maintenance DE requirements of donkeys in Mexico, did report a significant ($P<0.05$) increase in requirements in spring (9.3^{o}C) compared to DEI in summer, autumn and winter (temperatures not provided). The donkeys in the present study required more DE (MJ/kg $BW^{0.75}$) in winter compared to all other seasons. The almost 50% increase in DEI from autumn to winter (Figure 4.4), combined with near maintenance of body weight in all seasons, shows the higher DEI's in winter were due to higher DE requirements. As the donkeys were managed in the same routine, it could be assumed that the cause of the increased energy demands in winter was the colder environmental temperatures. Ambient temperature ranged from 5.1 – 12.3^{o}C in autumn (mean 8.7^{o}C) and 2.1 – 7.0^{o}C in winter (mean 4.6^{o}C) (Met Office, Devon, UK). Dry matter intake also increased from summer to winter and then decreased again in spring. This pattern of DMI shows a response to changing DE requirements, increasing food intake to gain more energy or to compensate for greater energy loss. However, the donkeys were unable to maintain body weight on the straw based ration in the winter season, requiring a ration of higher hay content and digestibility to be fed. The effect of season on DMI, and the need to feed more hay in the winter ration, may have been solely a response to the higher energy requirements in winter. However, the need to feed more hay may have been due to a seasonal variation in food intake that is exhibited by other herbivores in response to changing photoperiod (Rhind, Archer & Adam, 2002). Photoperiod affected DMI in Red deer through daily feeding time, increasing meal duration and reducing inter-meal intervals in long photoperiods, and having the opposite affect in short photoperiods (Rhind *et al.*, 1998). If the donkeys in this study had a similar response to photoperiod, DMI in winter would have been the lowest when DE requirements were at their maximum, requiring more energy to be consumed per kg DM eaten. The effect of season on food intake by the donkeys is not immediately clear from intake results shown in Table 4.4, due to the change in diet offered, and the need to maintain body weight throughout the study. The need to increase the hay portion of the winter ration may have been solely due to higher DE requirements and the donkeys being unable to consume enough straw due its low energy content and rate of intake. However, a seasonal reduction in DMI may also have required donkeys to consume a higher energy diet to compensate for eating less. Had the donkeys continued to consume the low energy (6MJ/kg DM) autumn ration in winter, DMI would have had to increase to 3.5 and 3.3kg per day compared to the 2.47 and 2.39

kg per day achieved during the autumn (Table 4.4) for geldings and females respectively, to satisfy energy requirements in winter; assuming an unchanged digestibility at the higher intake. This equates to an increase of 0.20 and 0.33kg DM per day for geldings and females respectively. Comparison of DMI required by donkeys if fed on the autumn ration, with actual DMI by donkeys in winter (paired t-test), showed required DMI would be significantly greater ($P<0.05$). This suggests that the donkeys had to be fed the higher energy winter ration because there was a slight seasonal reduction in DMI. However, it is more likely the donkeys were unable to maintain body weight on the autumn ration due to the longer handling time and slower intake rate when eating high fibre straw, limiting DM and DE intake.

The variation in DCP intakes by the donkeys was primarily due to variation in DMI and forage CP content, and therefore it is unlikely that these results accurately represent DCP requirements. The very low CP content, and significantly lower CP digestibility of the autumn ration, resulted in a decrease in DCP intake from summer to autumn and produced a large increase in DCP intake from autumn to winter that is not representative of DCP requirements. To gain an accurate measurement of maintenance DCP requirements of donkeys requires further investigation, although in horses protein deficiencies are rare if adequate energy is fed (Frape, 2004). The absence of signs of protein deficiency in the donkeys in this study suggests the same is true for donkeys, as assessed by coat growth and hoof condition.

4.4.6 Comparison with Horse Recommendations

The ability of donkeys to survive on poor quality diets is due to an efficient utilisation of fibrous plant fractions. Direct comparisons of digestive efficiency between donkeys, horses and ponies show that donkeys digest diets to greater extent

(Tisserand *et al*., 1990; Pearson & Merritt, 1991; Cuddeford *et al*., 1995; Pearson et *al*., 2001). As passage rate is the primary determinant of fermentation rate (Van Soest, 1982), the longer digesta retention time in donkeys, compared to horses and ponies (Pearson & Merritt, 1991; Cuddeford *et al*., 1995; Pearson *et al*., 2001), even when DMI's are similar, is the primary method by which donkeys achieve greater digestive efficiency. The reduced effect of DMI on retention time in donkeys may be due to greater caecal and colon capacity compared to horses (Kobayashi *et al*., 2006; Sneddon, Boomker & Howard, 2006). Kobayashi *et al*. (2006) reported greater caecal and colon capacity in native Japanese Hokkaido ponies compared to Thoroughbred horses managed under the same husbandry system. Sneddon *et al*. (2006) also reported GIT volume, as percentage of body weight, to be greater in donkeys (~20%) compared to that reported for horses (~11%) (Adolph, 1949). A larger GIT capacity would enable donkeys to maintain DMI without increasing digesta passage rate. Studies by Julliand and colleagues (1997; 1998) also indicate that donkeys may degrade cellulose to a greater extent than ponies due to faster growth of the cellulose degrading fungi *P. citronii* in the donkey caecum compared to the caecum of ponies. Faster degradation would further enable maintenance of DMI due to a rapid breakdown of digesta within the hindgut.

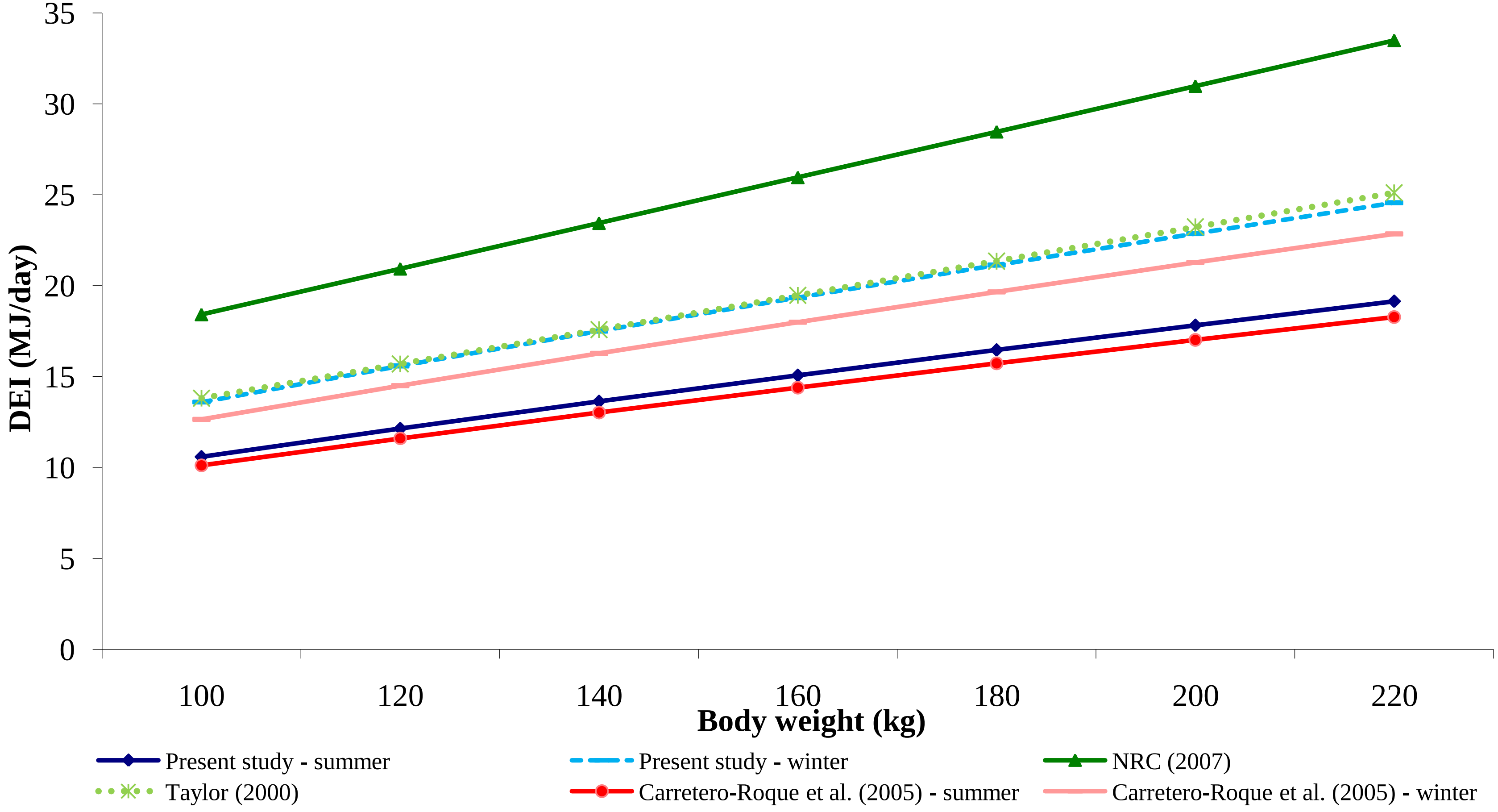
Donkeys in this study digested the diets of straw and hay comparably to donkeys in previous studies. The more complete digestion of foods by donkeys effectively increases the energy density of the ration, reducing the quantity of food required to satisfy energy requirements. Daily DMI by the donkeys in this study (12 – 18g DM/kg BW) were generally lower than is recommended for horse rations (15 – 25g DM/kg BW). From the smaller appetites of donkeys, combined with their greater digestive efficiency, it could be assumed that donkeys require diets of similar quality and energy density to horses, but in smaller amounts. This assumption was used in the feeding recommendations proposed by McCarthy (1989) and Taylor (2000), recommending feeding 0.75 of horse rations. Due to the absence of information on the DE requirements of donkeys, no account could be made for differences in energy requirements between the two species, and thus differences in the quality of the diet required.

Results from this study on donkeys in the UK, and the study by Carretero-Roque *et al*. (2005) on Mexican donkeys, show that donkeys have considerably lower maintenance DE requirements than horses. Current horse recommendations (NRC, 2007) estimate DE requirements, on a metabolic body weight basis, of donkeys in the present study, as 0.58 and 0.56MJ during summer and winter, overestimating actual intakes by the donkeys in the present study by 82 and 30%, respectively. This margin of error is even greater for the Mexico donkeys, estimating DE requirements in summer and winter as 100 and 52% more than actual energy intakes, respectively. Figure 4.9 shows calculated energy requirements using results from this study, the study in Mexico and current horse (NRC, 2007) and donkey (Taylor, 2000) recommendations, for donkeys ranging in body weight from 100 to 220kg. Digestible energy requirements calculated using the horse recommendations significantly overestimated energy requirements compared to those calculated using all other systems ($P<0.001$). Recommendations by Taylor (2000) also significantly overestimated maintenance requirements of donkeys in this study during summer, and donkeys in the Mexico study during summer and winter ($P<0.001$).

From these results it appears that donkeys have lower energy requirements for maintenance than horses, and that horse recommendations are not suitable for calculating donkey energy requirements. The lower energy requirements of donkeys also make current donkey recommendations only suitable for calculating donkey requirements during winter.

The feeding strategy of the donkey differs from that of the horse, being one of lower food intake and energy requirements, and greater utilisation of food consumed. In practical terms, this means that foods fed to donkeys will generally have a higher DE value than when fed to horses. Therefore, feeding similar diets to donkeys as would be fed to horses, but in smaller quantities, as recommended by Taylor (2000), could result in excess energy intake due to the DE values of foods eaten by donkeys being higher than expected. A reduction in food intake may not counter act the higher digestibility and thus DEI by donkeys compared to that achieved by horses. To prevent excess energy intakes, low energy, high fibre diets are most suitable for feeding to non-working, mature donkeys in the UK.

Figure 4.9. Digestible energy requirements of donkeys for body weight range 100 to 220kg calculated using horse (NRC, 2007) and donkey (Taylor, 2000) recommendations compared with results gained in the present study in the UK and Mexico (Carretero-Roque *et al*., 2005).



4.5 CONCLUSIONS

This study was the first to investigate and report the maintenance DE requirements of mature donkeys in the UK. Dry matter, DE and DCP intakes were similar in geldings and females during all seasons, showing there is no effect of sex on nutrient requirements of donkeys. There was however, a significant effect of season. Digestible energy requirements were similar during summer, autumn and spring, with energy intakes in spring representing maintenance requirements most accurately. During winter energy requirements increased by approximately 50%, thought to be due to increased requirements for thermoregulation. In response to the greater energy demand in winter, food intake by donkeys also increases, although by proportionally less (~ 30%), requiring a higher energy ration to be fed during this season. Increasing the proportion of hay in the diet fed in winter satisfies this demand for a higher energy ration, removing the need to feed concentrate feeds to none working, healthy donkeys in the UK. It is concluded that daily maintenance DE requirements of donkeys in this study were 0.32MJ per kilogram of metabolic body weight, except during winter when requirements increase to 0.43MJ DE.

Determination of the maintenance DE requirements of donkeys has shown that feeding recommendations for horses are unsuitable for calculating the energy requirements of donkeys. Digestible energy requirements of donkeys in this study during summer and winter, as a proportion of metabolic body weight, were 55 and 77% of horse recommendations (NRC, 2007). Current donkey recommendations (Taylor, 2000) are also only suitable for calculating donkey requirements during winter, overestimating requirements by approximately 37% during summer, autumn and spring. Application of current donkey recommendations will increase the chance of owners overfeeding their donkeys for the majority of the year. For this reason, it is imperative that new feeding guidelines for donkeys be developed, accounting for the lower energy requirements of donkeys, and their ability to more efficiently utilise fibrous diets compared to horses. The findings that donkeys require considerably less energy but only slightly less DM than horses also confirms that forage based diets are the most suitable for feeding to donkeys. However, the preference for hay over straw observed in this study could lead to donkeys consuming excess energy if fed hay *ad libitum*, as reported previously by Pearson *et al*. (2001). Thus, a diet of low energy, high fibre straw, combined with smaller quantities of more digestible grass hay, will enable donkeys to satisfy appetite without consuming excess energy. Education of owners in the food types suitable for donkeys will help to improve donkey welfare as donkeys will be able to exhibit normal feeding behaviour due to the longer eating times incurred when consuming forages.

4.5.1 Future Work

This study was the first step in formulating feeding guidelines for donkeys in the UK, however, from Chapter 3 it is evident that any feeding guidelines for donkeys must aim to account for energy derived from pasture, and the effects of pasture restriction on pasture intake. The most common methods used by owners to restrict pasture intake are restriction of pasture access time, strip grazing and grazing area/stocking rate (set stocking), although the effectiveness of these methods on DM and DE intake from pasture is unknown. Investigations into the effects of strip grazing, set stocking and time restriction are therefore warranted to ensure the results of this study, and corresponding feeding guidelines for donkeys, are relevant to the practical husbandry systems used to manage donkeys in the UK.

CHAPTER 5
THE EFFECT OF MANAGEMENT PRACTICES ON DRY MATTER INTAKE BY GRAZING DONKEYS

5.1 INTRODUCTION

Results from the two previous chapters confirm that donkeys in temperate climates have lower maintenance DE requirements than horses and ponies, and that forages and pasture provide the bulk of nutrients in the diets of donkeys in the UK. The ability of hay and straw diets to meet donkey energy requirements has been confirmed through the digestibility studies reported in Chapter 4, however, the energy gained from pasture has yet to be determined. Commonly, donkeys in the UK have daily access to pasture, with this access being regulated by grazing area (set stocking), grazing access time and strip grazing, although the effects of these husbandry practices on pasture intake have not been investigated in donkeys. As a result, the effects of these common management techniques on pasture intake are unknown. To make feeding guidelines for donkeys applicable to the practical feeding situation it is imperative that the effects of these management techniques be investigated.

Determining food intake, diet composition and diet digestibility is more problematic in grazing animals, compared to housed animals, due to inaccuracies in the methodologies available compared to direct measurements available for housed animals. Estimates of food intake however can be gained from information on diet digestibility and faecal output using equation 5.1.

Equation 5.1.

$$\text{DMI} = \frac{\text{(Faecal Output)}}{\text{(1-Digestibility)}}$$

Markers can be used to estimate the digestibility and faecal output components of the above equation, and therefore enable the estimate of food intake. Markers are substances that are indigestible to the animal and recoverable in the faeces. Markers are particularly useful when measuring intake in grazing animals as composition and quantity of diet consumed can be estimated without the need for feeding known amounts of food or total faecal collections. In order to be suitable for predicting food intake, markers must be indigestible, easily recoverable through laboratory analysis, and have no effect on either the animal it is administered to, or the digestibility of the diet (Dove & Mayes, 1991). Internal markers are indigestible compounds found within the food consumed (e.g. lignin, acid-insoluble ash [AIA], indigestible-ADF and chromogen) that are used to estimate food digestibility through calculation of their concentration in the diet and faeces (Dove & Mayes, 1996). External markers are indigestible substances that are not found naturally in the diet or soil, and are either added to the diet or fed separately (Van Soest, 1994). Chromium sesquioxide (Cr_2O_3) is the most frequently used external marker. External markers are used to estimate faecal output and diet digestibility through calculation of their concentration in the faeces (Dove & Mayes, 1996).

Use of the internal and external markers highlighted above is not without problems. Schurg (1981) and Miraglia *et al.* (1999) showed acid–detergent lignin (ADL) underestimated DMD in horses, primarily due to insufficient recovery of ADL during faecal analysis. Acid-insoluble ash has been shown to overestimate digestibility, although not significantly, in horses (Cuddeford & Hughes, 1990; Miraglia *et al.*, 1999), although Bergero *et al.* (2004) found estimates of DM, OM and GE digestibilities using AIA were comparable with directly measured apparent digestibilities by four adult horses. Regression analysis of digestibilities using the marker and direct methods produced r^2 values ranging from 0.66 – 0.73 (Bergero *et al*., 2004). The accuracy of AIA to measure digestibility in grazing animals, however, may be affected by the presence of ash in the soil, leading to intake of ash from none dietary sources and overestimation of faecal ash content (Van Keulen & Young, 1977).

Errors in the estimation of intake can also arise from use of the external marker Cr_2O_3. The fine, dense nature of Cr_2O_3 makes it act like a liquid when suspended in water (Van Soest, 1994). As a result, Cr_2O_3 does not associate with the particulate phase of digesta within the GIT, passing through the GIT at a faster rate than the digesta it is intended to represent (Van Soest, 1994). The lack of association between marker and digesta leads to fluctuations in the excretion rate of the marker and diurnal variation in faecal Cr_2O_3 concentrations (Corbett *et al*., 1960; Cuddeford & Hughes, 1990; Dove & Mayes, 1991; Malossini *et al*., 1996). This variation in marker excretion can lead to incomplete faecal marker recovery and under (Prigge *et al*., 1981) and overestimates (Haenlein, Smith & Yoon, 1966; Knapka *et al*., 1967; Cuddeford & Hughes, 1990; Piasentier *et al*., 1995) of faecal output. Consequently, food intake estimates are also inaccurate. Increasing the frequency of marker dosing and faecal sampling can reduce the variation in faecal marker concentration, however, such practices increase disturbances to experimental animals and increase the amount of labour involved in the experiment (Brisson, Pigden & Sylvestre, 1957; Dove & Mayes, 1991; Malossini *et al*., 1996).

The development of the double dosing procedure using *n*-alkanes (hydrocarbons found in the wax of plant cuticles) as internal and external markers has removed the need to independently estimate digestibility and faecal output in order to estimate intake. Alkanes are carbon chains of varying length found naturally in plants. Typically alkanes range from 25 to 35 carbons, although shorter chain lengths may be present but in much smaller quantities (Dove & Mayes, 1991). Odd-chained alkanes are usually present in much greater quantities than even-chained alkanes, with C_{29} (nonacosane), C_{31} (hentriacontane) and C_{33} (tritriacontane) alkanes being the most dominant (Dove & Mayes, 1996). Analysis of alkane profiles is relatively easy using gas chromatography, making them suitable markers for estimating intake (Dove & Mayes, 1991). One possible argument against the use of alkanes as markers is the small amount of absorption of alkanes in the small intestine (Dove & Mayes, 1991), making them incompletely recoverable in faecal samples. However, the estimation of intake using alkanes uses faecal alkane concentrate ratios and not actual concentration values. If the naturally occurring odd-chain and the synthetically dosed even-chain alkanes have similar recovery rates, then the errors associated with incomplete recovery of internal and external markers are cancelled out (Penning, 2004).

5.1.1 Estimation of Intake using *N*-Alkanes

The higher concentration of odd-chain alkanes compared to even-chain alkanes in plants makes them ideal internal markers for estimating digestibility. The difference in odd and even-chain concentrations in plants also enables synthetic even-chain alkanes to be used as external markers to estimate faecal output. Adjacent alkanes of similar chain length (e.g. C_{31} and C_{32} or C_{32} and C_{33}) are used as their faecal recoveries are similar, enabling intake to be calculated using equation 5.2 (Doves & Mayes, 1991).

Equation 5.2.

$$DMI = \frac{(Fi/Fj \times Dj)}{(Hi - Fi/Fj \times Hj)}$$

Where:

Fi: Faecal odd chain alkane concentration
Hi: Herbage odd chain alkane concentration
Fj: Faecal even chain alkane concentration
Hj: Herbage even chain alkane concentration
Dj: Daily dose even chain alkane

Recovery rates of alkanes from ruminant faecal samples show variation dependant on alkane chain length. As chain length increases, faecal alkane recovery increases (Mayes *et al*., 1986; Ferreira *et al*., 2007a), requiring longer chain alkanes to be used for studies of ruminant animals and correction for incomplete alkane recovery (Ferreira *et al*., 2007b). Studies into recovery rates from equine faecal samples showed no effect of chain length (Ordakowski *et al*., 2001; Stevens, van Ryssen & Marais, 2002; Ferreira *et al*., 2007a; Smith *et al*., 2007), enabling alkanes that are not adjacent to be used as paired markers. The need for correction of incomplete alkane recoveries in equine faecal samples is uncertain. Ordakowski *et al*. (2001), Stevens *et al*. (2002) and Peiretti *et al*. (2006) found that the accuracy with which DMD was estimated in horses was increased, although not significantly, when using the alkane technique, if incomplete faecal recovery of alkanes was accounted for. Ferreira *et al*. (2007b) also found correction for incomplete alkane recovery had no significant effect on the accuracy with which diet composition was estimated. Calculating the recovery rate of alkanes requires animals to be fed a controlled diet to allow alkane intake to be accurately calculated. Dietary control over animals is best achieved through housing, however such studies are time consuming and expensive, and may be impractical when studying wild or grazing animals. The lack of any significant effect of correcting for incomplete recovery of alkanes in equids makes use of the alkane pair technique without correction suitable for use in equids, although the accuracy with which DMD and diet composition are estimated is likely to be increased if faecal recovery rates can be obtained.

Studies using the alkane pair technique to estimate DMD in horses have shown that DMD is underestimated compared to directly measured apparent DMD. Stevens *et al*. (2002) found that alkane estimated DMD was lower, although not statistically different, to directly measured DMD. The degree of error incurred using alkanes averaged 20% when incomplete faecal recoveries were not accounted for, but reduced to 5% when incomplete recoveries were accounted for. Peiretti *et al*. (2006) did not account for incomplete alkane faecal recovery and found directly measured DMD was underestimated by 4 – 9% when using alkanes. Peiretti and colleagues also found that alkane estimated DMD varied considerably between diets fed and odd-chain alkanes used. Between animal variations in directly measured DMD, however, were also reported, leading to the conclusion that DMD estimated using alkanes is comparable to that measured through conventional direct methods, and is particularly suited for use in grazing horses.

The use of *n*-alkanes for estimating DMI in housed equids has been reported in a number of studies. Stevens *et al*. (2002) reported similar estimates of daily DMI by stabled horses, using different alkane pairs (C_{31}:C_{32} and C_{32}:C_{33}), to those calculated using direct methods. Peiretti *et al*. (2006) also found no difference between DMI gained from alkanes and the direct method, in horses housed and fed forage only and forage and concentrate diets. In the same study the odd-chain alkane with the highest faecal recovery rate for each diet resulted in the most accurate estimate of DMI. Ferreira *et al*. (2007a) found alkane markers consistently overestimated DMI, although the degree of overestimation varied with alkane pairs used. Alkane pairs with similar faecal recovery rates estimated DMI with the greatest accuracy. Smith *et al*. (2007) also found that the odd-chain alkane with the closest recovery rate to that of the even-chain dosed alkane gave the most accurate DMI estimate in horses, donkeys and cattle, supporting the findings of Peiretti *et al*. (2006) and Ferreira *et al*. (2007a). In both the study by Smith *et al*. (2007) and that by Ferreira *et al*. (2007a), C_{31} alkane gave the most accurate DMI estimates. C_{31} was also the most abundant alkane in grass hays, straw, haylage and freshly cut ryegrass, heather and gorse, offered to equids in the studies by Ordakowski *et al*. (2001), Stevens *et al*. (2002), Peiretti *et al*. (2006), Ferreira *et al*. (2007a) and Smith *et al*. (2007). Donkeys in the UK are most commonly fed grass hays and straw (Chapter 3, Table 354), therefore it could be assumed that C_{31} would be the most suitable odd-chain alkane for estimating DMI and DMD in housed donkeys fed forage diets. The alkane concentrations of grass (*Lolium perenne, Dactylis glometata, Phleum pratense, Holcus lanatus*) and clover (*Trifolum*.) species commonly comprising UK grazing pastures, however, vary with plant species (Dove & Mayes, 1996). This variation in alkane concentration between plant species may make determining intake of grazing animals less accurate due to difficulty in selecting the most appropriate odd-chain alkane to use. The alkane technique has been used in two studies to estimate intake of grazing horses in Australia (Queensland - McMeniman, 2003; Victoria - Friend, Nash & Avery, 2004), although validation of results is difficult due to there being no alternative method available to gain accurate measurements of intake in grazing animals (Penning, 2004).

The alkane method offers advantages over previous methods of intake and digestibility estimation. Accurate estimation of food intake and diet digestibility, combined with a reduced disturbance to the study animal and ability to gain individual animal results, are the primary advantages. Although originally formulated for use in ruminant animals, recent validation of this technique in equids enables more detailed study into the feeding behaviour and preferences of grazing equids.

EXPERIMENT: THE EFFECT OF RESTRICTED GRAZING TIME IN DIFFERENT SEASONS ON DRY MATTER INTAKE

5.2 INTRODUCTION

Grazing access times of donkeys surveyed in Chapter 3, managed using the combination system, varied throughout the year. In summer, when energy requirements are lowest, donkeys averaged 11.5 hours per day at grass (Chapter 3, Figure 3.5). In winter, when energy requirements are generally at their highest, donkeys had significantly less time to graze, being restricted to approximately 8 hours per day. In addition, the number of donkeys managed with 24 hours pasture access appeared to increase in spring and summer (Chapter 3, Table 3.3). The potential consequences of such pasture access management are that donkeys may gain body weight in summer, and lose weight in winter, unless the feeding of other foods are adjusted accordingly. Minor adjustments to the types and quantities of supplementary foods offered to donkeys were evident in Chapter 3, although the lack of any significant difference in the amount of foods fed each season by owners using the combination system indicates, that in general, donkey owners do not account for seasonal differences in grazing times, or changes in pasture availability and quality.

The lack of information on intake by grazing equids and the affects of grazing time, make calculating additional dietary requirements difficult. The lower energy requirements and longer grazing periods of donkeys in summer may make the feeding of all additional supplementary foods unnecessary. Reducing the number, and quantity, of additional foods fed will simplify the feeding of donkeys and potentially reduce feeding costs. Similarly, the reduced grazing time of donkeys in winter may require owners to increase the amount of supplementary feed offered to their donkeys to prevent weight loss.

5.2.1 Study Aims

The study determined the daily vDMI by donkeys with 8, 12 and 23 hours access to pasture. Grazing times represent grazing access times of donkeys in the UK during different seasons (summer and autumn). Grazing facilities at the study site (The Donkey Sanctuary) prevent donkeys having access to pasture during winter, and thus prevented estimation of pasture intake during this season. Pasture intake was determined in summer (June) and autumn (September), at the start and end of the donkeys grazing season, so as to best represent differences in pasture availability and quality. Barley straw was also offered *ad libitum* to all donkeys, representing the provision of supplementary forage by donkey owners reported in Chapter 3, and in accordance with Donkey Sanctuary policy. Daily intake of pasture and barley straw was estimated from information on diet composition. Feeding behaviour, bite rate, and number of steps were recorded to assess for any effect of grazing time on grazing behaviour, grazing intensity and the degree of selectivity. The study aimed to:

1. Determine the effect of grazing time on intake by donkeys in Devon in summer and autumn
2. Assess the effect of grazing time on the feeding behaviour of donkeys

Research Objectives

- Using the *n*-alkane technique, estimate total daily DMI by donkeys with 8, 12 and 23 hours daily grazing access during summer and autumn
- Estimate the proportion of grass and supplementary barley straw in the diet of donkeys in each grazing group

- Calculate daily eating and grazing times for donkeys in each grazing group using a scan sampling technique
- Calculate bite rates and grazing intensity for donkeys in each grazing group using a focal observation technique

5.3 MATERIALS AND METHODS

5.3.1 Experimental Design

The study took place at Hurfords Farm, The Donkey Sanctuary, Sidmouth, Devon. The study consisted of two experimental periods; Period 1 represented the end of the grazing season when available pasture was sparse (autumn, August 25th – September 26th 2003), Period 2 represented the start of the grazing season when pasture was abundant (summer, May 18th – June 18th 2004). Each experimental period consisted of an adaptation phase (20 days), allowing the donkeys to become accustomed to their management routine, and a recording phase (12 days), when an *n*-alkane marker was administered, food and faecal samples were taken and behaviour observations recorded.

5.3.2 Animals and Management

The 20 donkeys (10 geldings, 10 female) used in the study to determine DE requirements were used in this experiment. Ten geldings (starting body weights 164 – 216kg) and 8 female (145 – 208kg) donkeys were used during the autumn experimental period, and 9 geldings (160 – 208kg) and 10 female (138 – 205kg) donkeys used during the summer experimental period. The donkeys were weighed daily between 11:30h and 12:00h using a weighbridge (Horseweigh, Powys, Wales, UK) for the duration of the study. The donkeys were managed in three grazing groups; Group 1 was restricted to 8 hours grazing access per day, Group 2 was restricted to 12 hours grazing access per day and Group 3 was allowed 23 hours grazing access per day (Table 5.1). The same grazing area (~0.7 ha) was used for the three groups resulting in all donkeys grazing together for 8 hours per day. Strip grazing, using an electric fence, was used to regulate the amount of fresh, ungrazed pasture available to the donkeys. Whilst the donkeys were in their individual stables between 11:00h and 12:00h, the length of the electric fence was moved approximately 1 meter per day exposing fresh ungrazed pasture. All other areas of the grazing area had been continuously grazed by the donkeys in the period prior to the study resulting in a uniform pasture of short length. Access to a yarded area with shelter, water and barley straw was available *ad libitum* to all donkeys at all times, with fresh barley straw being offered daily at 08:00h, 13:00h and 20:00h. When grazing access was restricted each group was limited to the yarded area. The donkeys followed routine farriery, dental, vaccination and parasitic treatments throughout the study according to normal Donkey Sanctuary policy.

Table 5.1. Pasture access times (hours/day) of three grazing groups during autumn and summer experimental periods

Time	Location		
	Group 1 (8 hours)	**Group 2 (12 hours)**	**Group 3 (23 hours)**
07:00h	Yard	Field	Field
11:00 – 12:00h	Individual stables		
12:00h	Field	Field	Field
20:00h	Yard	Yard	Field
07:00h	Yard	Field	Field

5.3.3 *N*-Alkane Marker

Preparation

Weetabix Minis (MW), (Weetabix Ltd, Kettering, Northamptonshire, UK) approximately 5cm in length, were chosen as the method for administering the *n*-alkane Dotriacontane (C_{32}) to the donkeys. Twenty-five grams of C_{32} was dissolved in 2 litres of heptane in a large conical flask using a hotplate stirrer set at a low heat. Two millilitres of the alkane/heptane solution was transferred to each MW and the heptane allowed to evaporate. This process was repeated until each wheat biscuit contained 50mg of C_{32}. After evaporation to dryness, the biscuits were oven cooked for 24 hours at 70^{o}C to ensure complete absorption of the C_{32} and evaporation of the heptane. All procedures involving heptane were carried out wearing gloves and within a fume cupboard.

Administration

During each experimental period each donkey received 3 MW per day for the 12 day recording period. Mini weetabix were fed at 07:00h, 13:00h and 20:00h, totalling 150mg of C_{32} marker per donkey per day.

5.3.4 Sample Collection

Daily samples of barley straw offered and fresh ungrazed pasture were taken for the final 9 days of each recording period. Grab samples were taken of each new straw bale opened and stored in airtight bags. At the end of each experimental period samples were pooled and chopped into approximately 5cm lengths. A subsample was then taken, weighed and dried at 60^{o}C in a force draft oven until a constant weight to determine DM. Dry samples were retained for nutritional analysis.

The fresh ungrazed pasture available to the donkeys was sampled daily using a 30 by 30cm quadrat. Three samples were taken (top, middle and bottom of the fresh pasture) at the same time each day (11:30h) prior to being grazed. For each quadrat the pasture was cut at approximately 2cm above soil level to mimic the close grazing of pasture by donkeys. Cuttings were placed into a metal dish of known weight, weighed and dried as for straw samples, and retained for nutritional analysis. Prior to analysis a subsample of each pasture sample was taken and pooled to produce one pasture sample that was analysed for its nutritional content.

One complete faecal deposit per donkey was collected daily for the last 5 days of each experimental period using a clean bucket. Each deposit was mixed thoroughly and a subsample taken (~250g). Subsamples were frozen until the end of each experimental period to prevent spoiling. At the end of each experimental period faecal samples were defrosted and a 50g subsample taken from each day's faecal deposit, and pooled on an individual donkey basis. Subsamples were weighed and dried as for straw, and retained for nutritional analysis.

5.3.5 Analysis

N-Alkane Analysis

Straw, pasture (0.2g per sample) and faecal (0.1g) samples were weighed in duplicate and analysed for *n*-alkane content as described by Dove and Mayes (2006). Dry matter intake was calculated using equation 5.2. Preferably the odd-chain alkane with a similar faecal concentration as the even-chain alkane is used to calculate DMI as the accuracy with which DMI is calculated is increased. Faecal C_{32} concentrations for the donkeys in this study however were intermediate of both C_{31} and C_{33} concentrations. Therefore DMI was calculated as the mean DMI using C_{31} and C_{33}

as the odd-chain alkanes. Diet composition was determined using a Diet Selection Calculator software package (EatWhat, Version 1.2, CSIRO, 1996), based on comparing diet and faecal alkane profiles.

Nutritional Analysis

Prior to analysis all dried samples (straw, pasture and faeces) were ground using a hammer mill through a 1mm screen.

Straw, pasture and faecal samples were analysed for rDM, GE, CP, NDF and ADF according to the methods reported by the Association of Official Analytic Chemists (1990). *In vitro* DMD was determined using the NCGD technique described by ANKOM technology (Ankom, 2006) (See 3.2.5, Food Sample Analysis).

5.3.6 Behaviour Observations

Focal Observations

Focal observations were used to assess grazing intensity and the degree of selectivity with which donkeys graze. Focal observations were made at 12:15h and 16:00h each day for the first 5 days of each recording period. During each focal observation session, each donkey was observed for 5 minutes and the number of bites made and steps taken were counted and recorded using two hand-held tally counters. A countdown timer was used to measure the observation period.

Three observers were used during each observation session, each observing one grazing group. All of the donkeys in each grazing group were observed in turn, with the order of observation being rotated between each session to remove any effect of diurnal variation. Any effect of observer error was reduced by exchanging observed grazing group after each observation session.

Prior to the study period, the donkeys were followed whilst grazing for short periods on a daily basis so as to accustom them to people being in close proximity (5 - 10m) when they were grazing. This enabled observers to watch and listen for bites. A bite was defined as the grasping and severing of material from the remainder of the plant. A step was defined as the movement of the donkey's right front leg off the ground that resulted in the body moving forward. Any other movements of the front leg (fidgeting or fly removal) were not counted. Donkeys had to be actively grazing before their individual observation period could commence. If a donkey was not actively grazing at the start of their observation period, the next donkey in sequence was observed, and the original donkey observed out of sequence. If a donkey did not graze at any point during the observation session, then the number of bites and steps for that donkey was recorded as zero.

Grazing intensity was calculated as the number of bites per minute. Selectivity was calculated as the number of bites per step.

Scan Observations

Scan observations were used to determine time budgets for feeding behaviour. Scan observations were carried out at 5 minute intervals between 07:00h and 22:00h and at 15 minute intervals between 22:00h and 07:00h for a total of 72 hours. Observation sessions were split into 3 hour periods with a new observer for each session. A hand-held Psion datalogger was used to record observed behaviours and to notify the observer when the observation interval had elapsed.

Feeding behaviours that were recorded included eating straw, grazing, drinking, using the salt lick and nothing. Each of these behaviour options, and each donkey's name, were entered into the datalogger, and each donkey sampled in turn at each observation interval. After all 72 hours of data were collected the number of times each behaviour occurred per hour was calculated, allowing the mean number of minutes per hour donkeys in each group spent exhibiting each behaviour state to be calculated.

Calculation Method for Circadian Distribution of Donkey Behaviour

For each donkey behaviours were calculated on a minute per hour basis by firstly dividing the day into twenty-four 1 hour periods, then dividing each hour by the number of observations made during that period.

Example:

Minutes spent eating between 07:00h and 08:00h over 3 days observation period when a total of 16 observations were made =

3 x 1 hour = 180 minutes

180 minutes / 16 observations = 11.25 minutes per observation

So for a donkey observed eating 3 times between 07:00h and 08:00h =

3 x 11.25 minutes = 33.75 minutes spent eating between 07:00h and 08:00h

For each donkey the same calculation was carried out for each hour and each behaviour. For each grazing group the mean number of minutes spent exhibiting each behaviour could then be calculated.

5.3.7 Statistical Analysis

Statistical analysis was based on donkeys being randomly assigned to three blocks (grazing groups) with each block receiving a different treatment (grazing hours). All data was tested for normality and equality of variance using Minitab 15 (Minitab Ltd, Coventry, UK). Where data was normal the mean and standard error were calculated. Where data was not normal the median and interquartile ranges were reported.

Results for DM and DE intakes were normal, therefore any effect of season and grazing group was tested using general linear model two-way ANOVA to account for differences in the number of donkeys during each season and between grazing groups during season 2. Two-way ANOVA was also used to analyse results for feeding behaviour. Specific differences between grazing groups were identified using the Tukey test. Data on diet composition was not normal, therefore the Kruskal-Wallis test was used to assess for differences between grazing groups and differences between seasons. The Kruskal-Wallis test was also used to assess for differences in grazing intensity and selectivity between groups and season.

5.4 RESULTS

5.4.1 Food Offered

The proximate analysis of the barley straw offered and fresh pasture available during each season are shown in Table 5.2. The barley straws fed during each season were from different harvests, but were similar in nutrient content, and produced the same low *in vitro* DMD result. Grazing pasture was a mixture of grasses (*Lolium perenne*, *Holcus lanatus*, *Festuca rubra*, *Cynosurus cristatus*, *Dactylis glomerata*), herbs (*Taraxacum officinale*, *Bellis perennis*, *Stellaria media*, *Plantago major*, *Urtica dioica*, *Rumex obtusifolius*, *Ranunculus acris*) and the legume white clover (*Trifolium repens*). Pasture samples from both seasons contained the same amount of GE, although CP levels were considerably higher in autumn than during summer, indicating that the grazing pasture in autumn contained material of greater nutritional value. Autumn grasses, however, are reported to have lower soluble carbohydrate levels than equivalently mature spring grasses, explaining the higher NDF and ADF levels and the lower DMD of the autumn pasture. It is concluded that the lower fibre and higher soluble carbohydrate content of the summer grasses provided the donkeys with a more digestible pasture, evident by a higher *in vitro* digestibility value and higher grass intakes (Figures 5.3 and 5.4). Energy density of diets consumed by donkeys during summer, however, were lower than those consumed in autumn despite higher DMI (Table 5.3), indicating that the summer pasture was comprised of less nutritious material.

5.4.2 Food Intake

Table 5.3 shows the mean calculated DMI and estimated DEI for donkeys in each grazing group. The effect of season on DMI by donkeys was significant ($P<0.05$).

During summer, when pasture was more abundant, food intake by donkeys restricted to 8 hours pasture access per day and those with continuous access, was higher compared to intakes in autumn, with this increase being greatest in the 8 hours grazing group. Dry matter intakes by donkeys in the 12 hour grazing group were not affected by season with donkeys consuming the same quantity of food in both autumn and summer.

Pasture access time influenced DMI (kg/day and g/kg $BW^{0.75}$) during both seasons, although differences between grazing groups were not statistically significant. During autumn there was a suggestion of a trend in pasture intake, with daily DMI (kg/day) increasing with access time. However, proportional to metabolic body weight, the donkeys with 12 hours pasture access time consumed the most whilst those restricted to 8 hours per day consumed the least.

This trend did not apply to summer grazing. On a daily basis the highest intakes were associated with the longest access times, although the lowest intakes were measured in the 12 hour group. Donkeys in the 12 hour group also consumed the least on a metabolic body weight basis, whilst mean intakes for the 8 and 23 hour groups were the same (58g/kg $BW^{0.75}$).

Table 5.2. Nutritional composition of foods offered during each season (g/kg DM unless otherwise stated)

	Period 1 Autumn (Aug – Sep)		**Period 2 Summer (May – Jun)**	
	Pasture (*n*)	**Straw (*n*)**	**Pasture (*n*)**	**Straw(*n*)**
DM (g/kg)	268 (27)	884 (1)	308 (25)	935 (1)
GE (MJ/kg DM)	16.9 (3)	17.2 (1)	16.9 (1)	16.4 (1)
CP	125 (3)	33 (1)	67 (8)	28 (1)
NDF	677 (9)	888 (2)	569 (16)	806 (2)
ADF	354 (9)	575 (2)	318 (4)	556 (2)
† *In vitro* DMD	0.60 (9)	0.37 (2)	0.65 (16)	0.37 (2)

n: number of analysed samples per season

† *In vitro* dry matter digestibility determined via NCGD analysis (neutral cellulase plus gamanase)

Table 5.3. Mean ($\pm$ s.e.) daily dry matter intake (DMI), digestible energy intake (DEI) (pasture and straw combined) and dry matter digestibility (DMD) by donkeys restricted to 8, 12 and 23 hours grazing access per day during autumn and summer

	% of Total Intake		DMI						DEI				Diet Energy Density *	
Grazing Group (*n*)	**Grass**	**Straw**	**kg/ day**	s.e.	**g/kg $BW^{0.75}$**	s.e.	**DMD**	s.e.	**MJ/ day**	s.e.	**MJ/kg $BW^{0.75}$**	s.e.	**MJ/ kg DM**	s.e.
Period 1														
Autumn (Aug – Sep)														
Herbage mass $\pm$ s.e. (g DM/m^2)							**92 $\pm$ 7**							
8 hours (6)	18	82	2.26	0.117	45	2.0	0.40 a	0.017	19.7	1.25	0.39	0.028	8.7	0.34
12 hours (6)	18	82	2.54	0.241	56	5.8	0.34 a,b	0.017	20.1	2.60	0.44	0.063	7.8	0.43
23 hours (6)	11	89	2.61	0.139	49	2.2	0.32 b	0.030	19.4	2.05	0.37	0.041	7.6	0.92
Significance of effect of grazing hours	*	*	NS		NS		*		NS		NS		NS	
Period 2														
Summer (May – Jun)														
Herbage mass $\pm$ s.e. (g DM/m^2)							**197 $\pm$ 12**							
8 hours (6)	25	75	2.95	0.284	58	4.7	0.56 c	0.013	21.0	2.93	0.41	0.049	7.0	0.36
12 hours (7)	29	71	2.51	0.185	55	3.8	0.49 c,d	0.030	14.4	2.20	0.32	0.047	5.6	0.56
23 hours (6)	41	59	3.09	0.159	58	3.1	0.45 d	0.012	19.0	1.07	0.36	0.021	6.1	0.11
Significance of effect of grazing hours	***	***	NS		NS		*		NS		NS		NS	
Significance of effect of season	***	***	*		*		***		NS		NS		***	

a, b, c, d: Means in the same column bearing different letters differ significantly
NS: Not significant, * P<0.05, ** P<0.01, *** P<0.001
* Energy density of straw and pasture combined
n: Number of animals in group

Digestibility of diets consumed by donkeys restricted to 8 hours grazing per day were significantly ($P<0.05$) higher than those of donkeys with 23 hours pasture access during both seasons (Table 5.3). During autumn this greater digestive efficiency by donkeys in the 8 hour group was due to a higher proportion of grass in the diet (Figure 5.3), however, in summer donkeys in the 8 hour group consumed less grass than those with 23 hours pasture access. The lower DMI of donkeys restricted to 8 hours pasture access likely slowed the passage rate of digesta through the GIT. A slower rate of passage and difference in diet composition of donkeys in the 8 hour group would explain the higher apparent DMD results gained in this study during both seasons. As a result of more efficient digestion and higher grass intakes in autumn, the energy density of the diet consumed by donkeys with 8 hours grazing per day was the highest of all 3 grazing groups during both seasons.

Regression analysis was used to test for relationships between diet composition, DMI and DMD during each season, and when both autumn and summer data were combined. There was no relationship shown between DMD and diet composition during autumn, however during summer grass and straw intake had a significant effect on DMD. Dry matter digestibility increased in summer as straw intake increased and grass intake decreased (DMD = 0.432 + 0.0850 Straw (kg/day) - 0.109 Grass (kg/day), r^2 = 57%, P=0.001) (Figure 5.1). A weaker relationship was found between diet and DMD when data from both seasons were combined, with DMD increasing with increasing grass intake (DMD = 0.335 + 0.0087 Straw (kg/day) + 0.116 Grass (kg/day), r^2 = 17% $P<0.05$) (Figure 5.2).

Figure 5.1. Multiple regression analysis of dry matter digestibility (DMD) vs. grass and straw intake (kg/day) by all grazing groups during summer

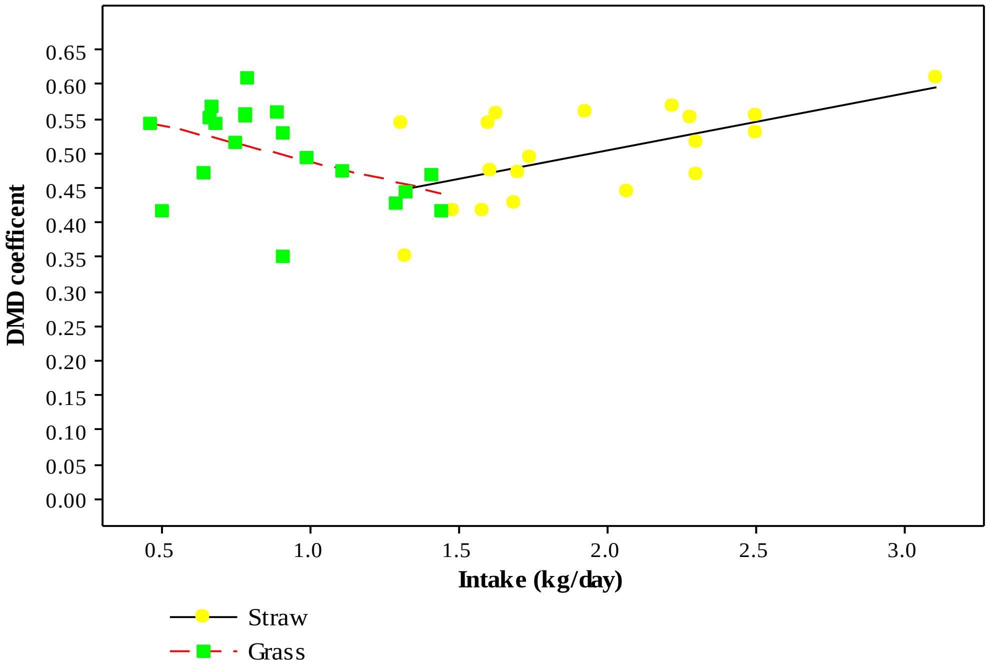
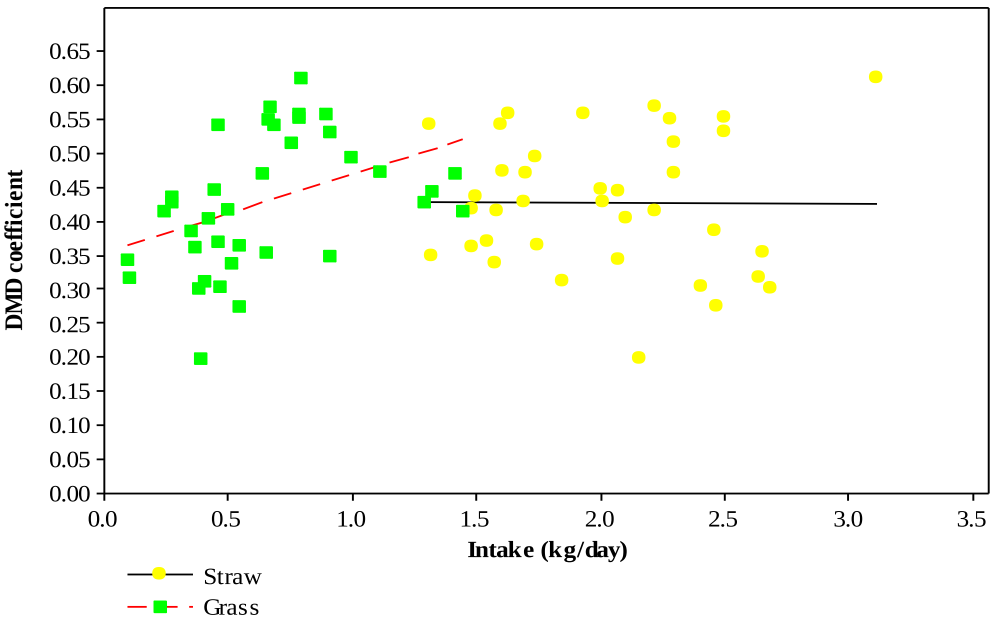


Figure 5.2. Regression analysis of dry matter digestibility (DMD) vs. grass and straw intake (kg/day) by all donkeys during both autumn and summer combined



Digestible Energy Intake

Digestible energy intakes by donkeys in autumn did not differ significantly between grazing groups. Respectively, donkeys in the 12 and 23 hour groups consumed the most and least amount of DE on a daily and metabolic body weight basis. The higher DE content of the grass (10.1MJ DE/kg DM) compared to the straw (6.4MJ DE/kg DM), combined with a higher grass and DM intake resulted in the higher DEI for the 12 hour group. Donkeys in the 23 hour group consumed the least amount of grass and most amount of straw, reducing the energy density of the diet consumed, and thus DEI.

Diets consumed in summer were more digestible than those consumed in autumn ($P<0.001$). This greater utilisation of the summer diets is as a result of donkeys consuming proportionally more grass in the summer compared to during the autumn. The more digestible diets consumed by donkeys with 8 hours pasture access per day resulted in the highest DEI compared to intakes by donkeys in the other grazing groups. Despite all donkeys consuming more digestible diets in summer, DEI were statistically similar between seasons due to the poor quality of the summer pasture, expressed by the significantly lower energy density of the diets consumed in summer ($P<0.001$).

5.4.3 Diet Composition

Composition of the diets selected by the donkeys was affected by pasture access time and season (Figures 5.3 and 5.4). During autumn, the diets of donkeys with 8 and 12 hours pasture access comprised of 18% grass and 82% straw, whilst the diets of the 23 hour group comprised of only 11% grass ($P<0.05$), although differences in the quantity of DM consumed as grass and straw by donkeys in each group were not significant (Figure 5.4).

During summer, the proportion of grass in the diet of donkeys increased with longer grazing time. Respectively, the diets of donkeys with 8 and 12 hours grazing access contained 25 and 29% grass, significantly less than the diets of donkey in the 23 hour group (41%) ($P<0.001$). Donkeys with 12 hours grazing consumed the least amount of DM as grass (Figure 5.3), whilst those in the 23 hour grazing group ate significantly more grass ($P<0.001$). Donkeys in the 8 hour group consumed more straw per day than those in the 12 and 23 hour groups, although this difference was not significant.

In both seasons donkeys in all grazing groups selected to eat more straw than grass. Season significantly affected diet composition ($P<0.001$), with the proportion of grass in the diet increasing when pasture was more abundant (summer) in all grazing groups, indicating an effect of pasture availability on diet selection. Similarly, the amount of DM (kg/day) gained from grass was significantly higher in summer. However, the amount of DM gained from straw was not significantly influenced by pasture availability, although there was a trend for higher straw intakes when donkeys consumed less pasture, either as a result of shorter grazing periods or a seasonal reduction in pasture availability

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Figure 5.3. Mean proportions of grass and straw comprising the diets of donkeys with 8, 12 and 23 hours grazing access during autumn and summer
Numbers in parenthesis represent number of donkeys in each group

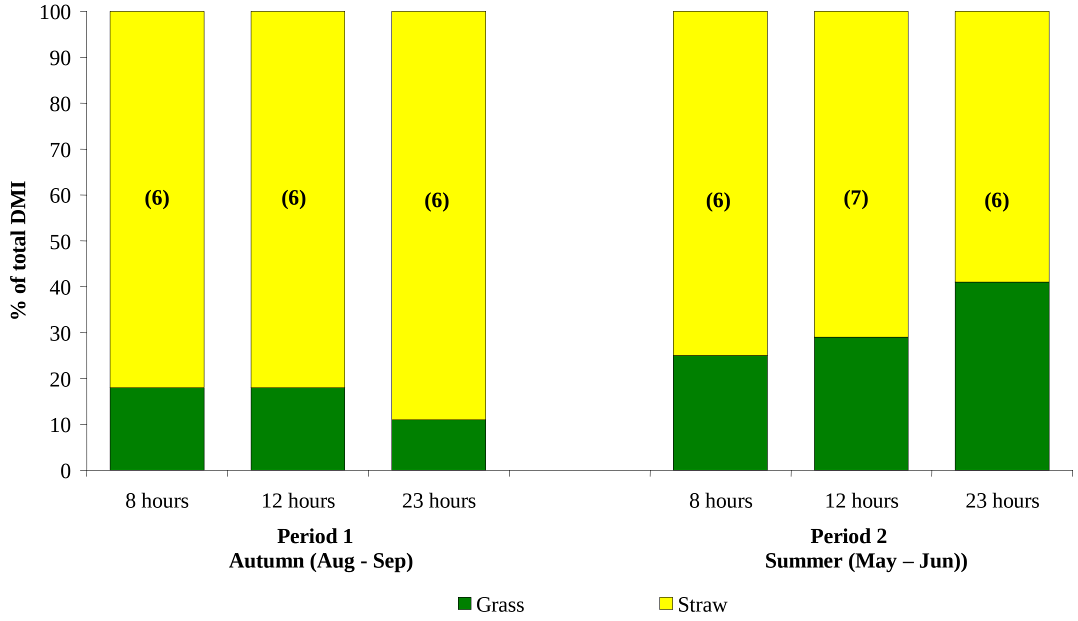
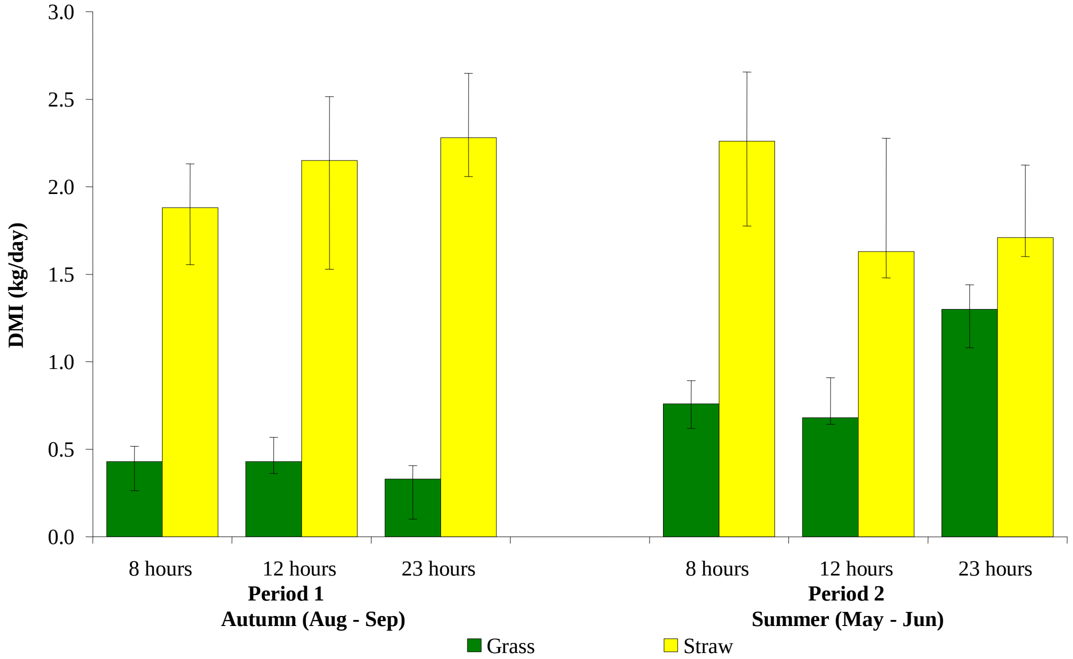


Figure 5.4. Median (interquartile range) daily dry matter intake (DMI) of grass and straw by donkeys with 8, 12 and 23 hours grazing access during autumn and summer
Same number of donkeys used as Figure 5.3



5.4.4 Behaviour Observations

Grazing Intensity

Grazing intensity, measured using bites per minute, was not significantly affected by pasture access time (Figure 5.5), although donkeys with 23 hours access to pasture grazed slightly more intensively than those with 12 or 8 hours access at both observation times and during both seasons. Observation time and season affected grazing intensity significantly. During autumn donkeys grazed more intensively at 12:15h when fresh, ungrazed pasture was available ($P<0.01$). However, during summer donkeys took more bites per minute at 16:00h ($P<0.001$). At both observation times donkeys grazed more intensively during summer than during autumn ($P<0.001$). The greater intensity that donkeys grazed during summer was therefore not only due to the fresh, ungrazed pasture being of greater herbage mass compared to herbage mass in autumn (197g DM/m^2 vs. 92g DM/m^2), but also due to more grass being available in the remainder of the field, although herbage mass of the previously grazed areas was not measured. Differences in grazing intensity between observation times (12:15h and 16:00h) were greater for donkeys in the 8 hour group during both seasons compared to donkeys with 12 and 23 hours grazing access.

Selectivity

The degree of selectivity exhibited by the donkeys was estimated using bites per step. Pasture access time did not significantly affect selectivity, although donkeys with 23 and 12 hours grazing access were the least selective grazers during autumn and summer respectively (Figure 5.6). In both seasons donkeys restricted to 8 hours pasture access were most selective, taking the least number of bites per step.

The number of bites taken per step was significantly higher at 12:15h than at 16:00h in all donkeys during autumn ($P<0.001$). Donkeys in the 12 and 23 hour grazing groups were also less selective at 12:15h during summer, however, donkeys restricted to 8 hours grazing appeared to be more selective at 12:15h. Season did not significantly affect bites per step ($P>0.05$), although donkeys were generally more selective during autumn when pasture was sparse, with the effect of pasture availability being greatest on donkeys restricted to 8 and 12 hours grazing per day.

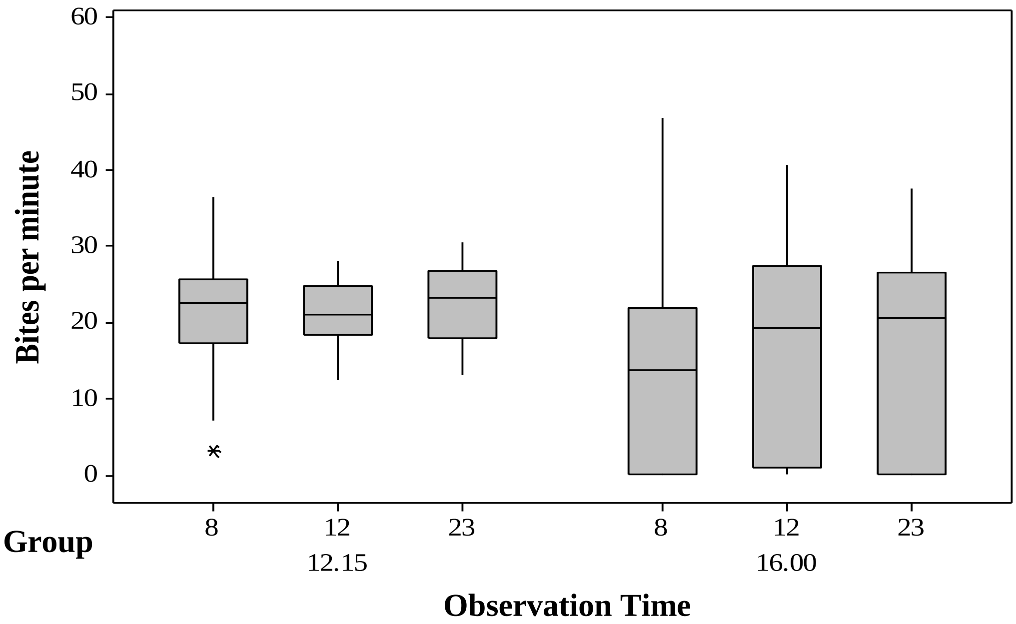
Feeding Behaviour

Total time spent feeding (grazing plus straw) was influenced by pasture access time. In the autumn the 8 hour access group (10:18h) spent less time feeding than either the 12 hour (11:48h) or 23 hour (11:12h) groups, although this was only statistically significant ($P<0.05$) in the case of the 12 hour group. The time spent feeding (grazing plus straw) in the summer was very similar in all groups (12:30h, 12:42h and 12:24h for the 8, 12 and 23 hour groups), with none of the differences being significant statistically.

In the autumn time spent grazing was least for the 8 hour group at 4:42h, however differences from the 12 hour (5:30h) and 23 hour (5:20h) groups were not statistically significant. In the summer the 12 hour group (6:43h) spent the most time grazing compared to either the 8 hour (5:46h) or 23 hour (5:42h) groups, although this was only statistically significant ($P<0.05$) in the case of the 23 hour group. Donkeys also spent more time grazing during summer than during autumn (6:01h vs. 5:10h, respectively) ($P=0.01$).

Figure 5.5. Box and whisker plot showing the number of bites per minute donkeys in each grazing group took during a 5 minute observation period at 12:15 and 16:00. * Outlier values

(a) Autumn (Aug - Sep)
6 observations per group per observation time



(b) Summer (May – Jun)
6 observations for the 8 and 23 hour groups per observation time
7 observations for the 12 hour group per observation time

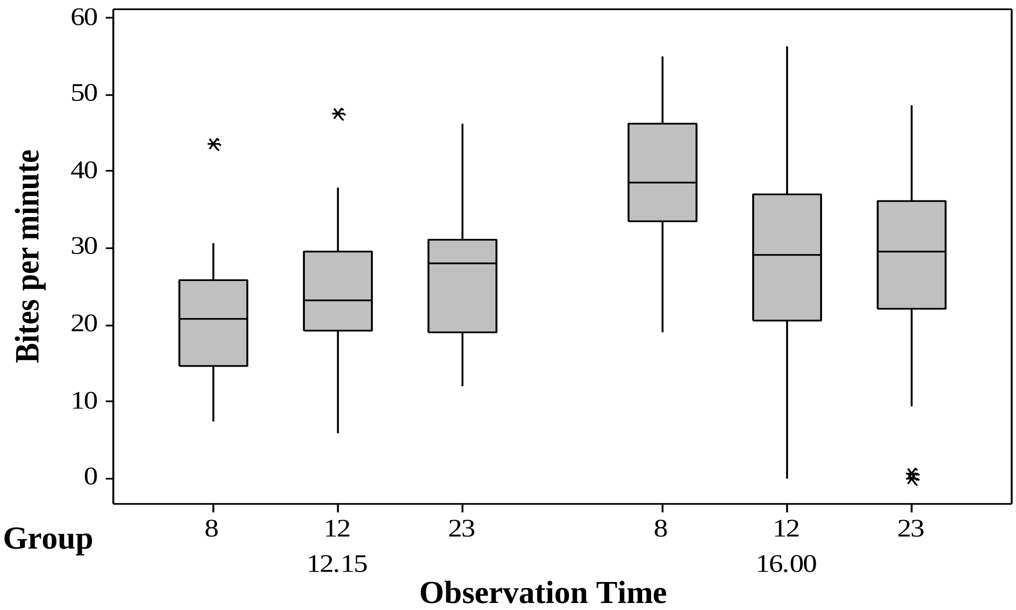
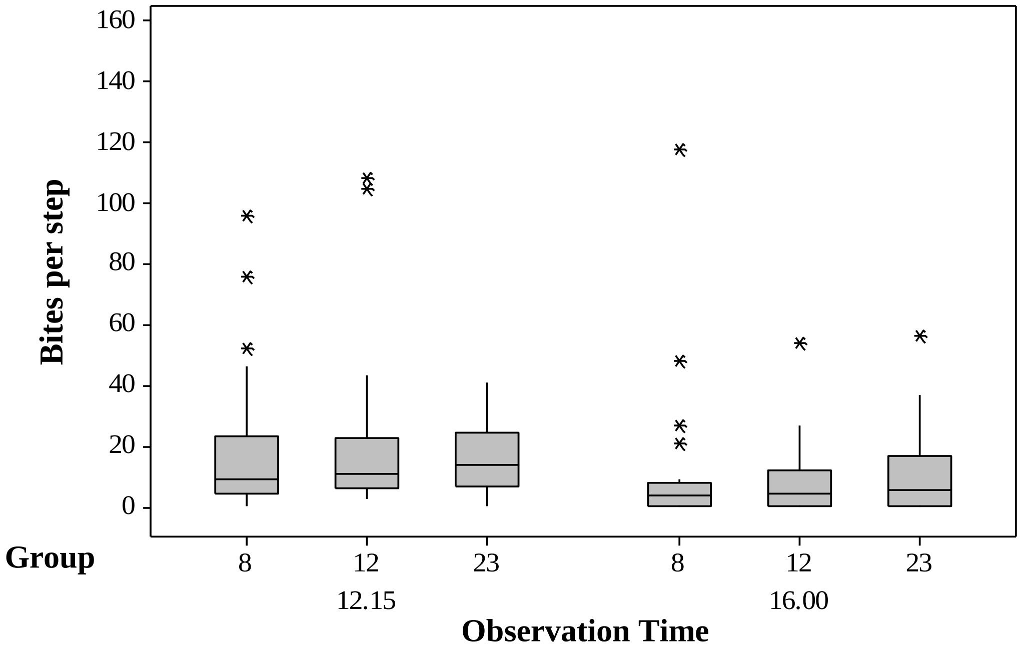


Figure 5.6. Box and whisker plot showing the number of bites per step donkeys in each grazing group took during a 5 minute observation period at 12:15 and 16:00. * Outlier values

(a) Autumn (Aug – Sep)
Same number of observations per group and time as Figure 5.5 (a)



(b) Summer (May – Jun)
Same number of observations per group and time as Figure 5.5 (b)

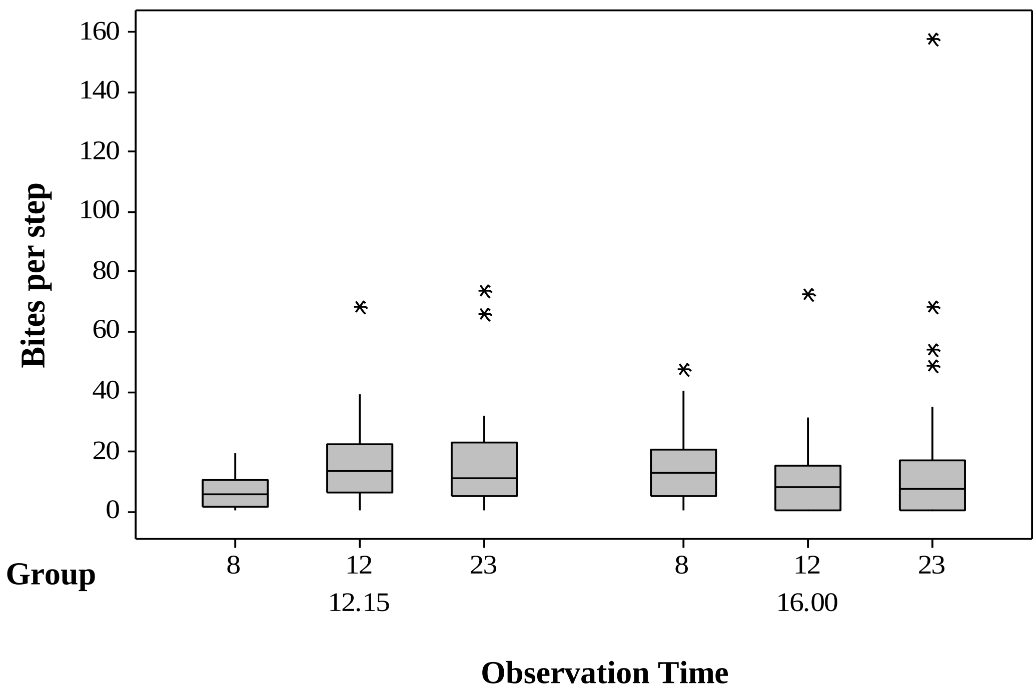
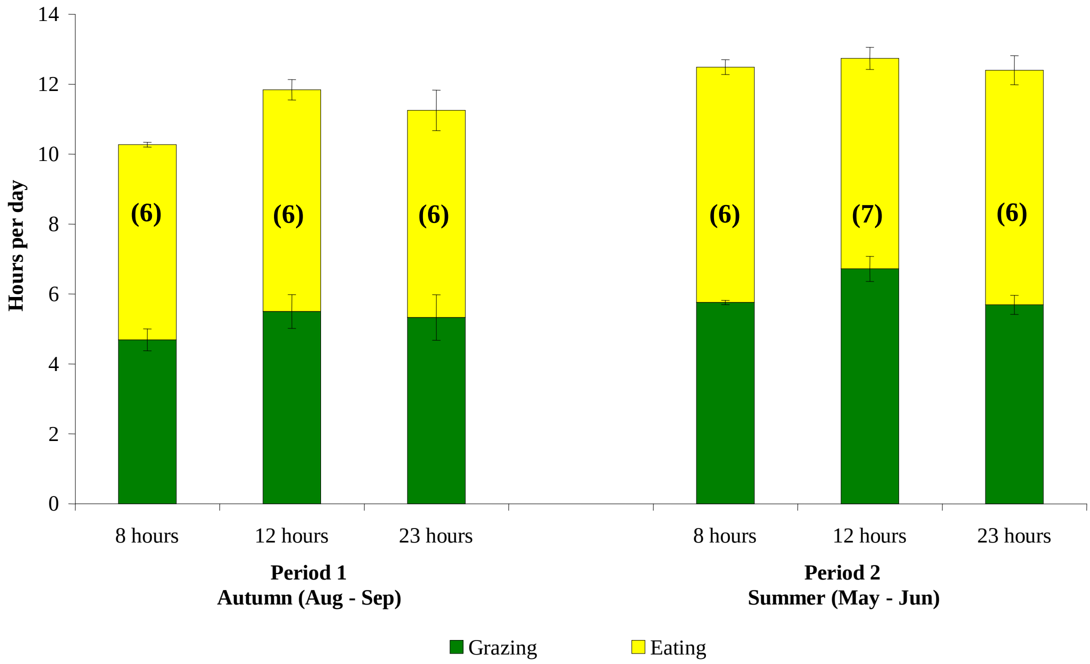


Figure 5.7. Mean (± s.e.) number of hours per day spent grazing and eating straw by donkeys with 8, 12 and 23 hours pasture access during autumn and summer
Numbers in parenthesis represent number of donkeys per group



Circadian Distribution of Feeding Behaviour

The circadian distributions of feeding behaviour, drinking and use of a salt lick by donkeys in each grazing group are shown in Figures 5.8 – 5.16.

8 Hour Grazing Group

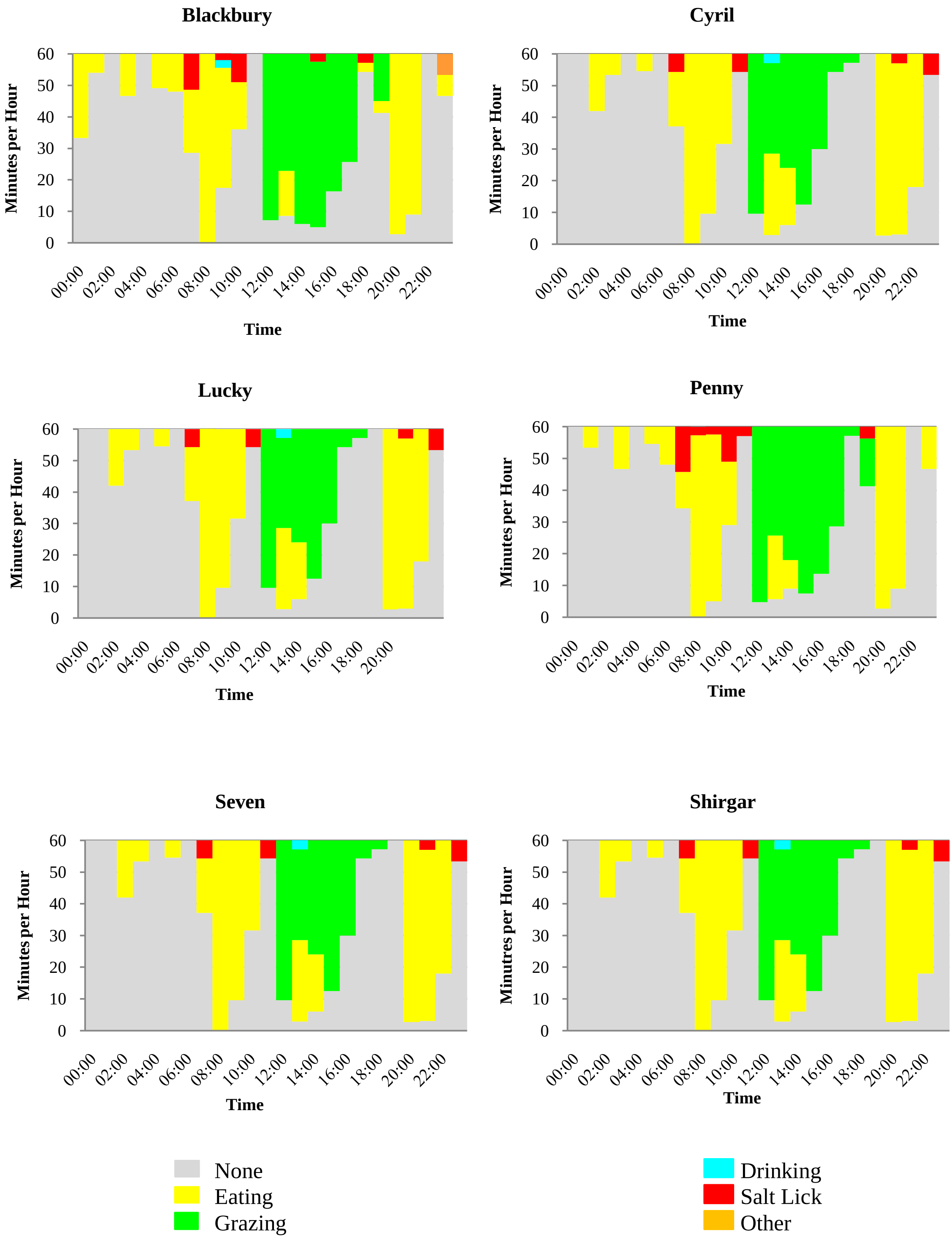
Circadian oral behaviours for individual donkeys restricted to 8 hours grazing per day are shown in Figure 5.8. All donkeys grazed for less time (hours/day) during autumn compared to during summer. A very low grazing time was recorded for Cyril during autumn at 3:18h/day, considerably less than all other donkeys in the group (4:33h – 5:45h/day) during this season. Time spent eating straw by Cyril (5:27h/day) in autumn was similar to all other donkeys in the group (5:04h – 5:45h/day), showing there was no substitution for reduced grazing time. The shorter grazing time in autumn resulted in a lower grass intake by Cyril (0.27kg DM/day) compared to the mean group intake of grass at 0.43kg DM/day. As a result DMI's on a daily and metabolic body weight basis by Cyril were considerably lower at 1.77kg and 36.7g DM/kg $BW^{0.75}$, compared to individual donkey intakes and the mean 8 hour group intake (8 hour group mean DMI: 2.26kg/day and 45g DM/kg $BW^{0.75}$).

Circadian oral behaviours for all donkeys in 8 hour group are shown in Figure 5.9. Donkeys restricted to 8 hours grazing per day had two obvious periods of eating straw that coincided with the feeding of fresh straw; Period 1 between 07:00h and 11:00h in both seasons and in Period 2 between 20:00h and 22:00h in autumn and 20:00h and 00:00h in summer. Offering fresh straw at 13:00h prompted donkeys to eat straw between 13:00h and 14:00h, although only for an average of 15 minutes in autumn and 5 minutes in summer. Eating of straw was observed throughout the day, although donkeys spent the majority of their time with access to pasture actively grazing. Of the total 8 hours donkeys were able to graze, donkeys spent on average 4:42h grazing and 2:52h eating straw during autumn and 5:44h grazing and 0:46h eating straw during summer.

During autumn, grazing time per hour progressively decreased from 17:00h until when the donkeys were restricted to the yard and barn areas at 20:00h. In autumn, donkeys grazed for approximately 47 minutes per hour between 12:00h and 17:00h. From 17:00h until 20:00h grazing time decreased to an average of 19 minutes per hour. In contrast, during summer the same donkeys continued to graze on average for 48 minutes per hour from 12:00h until 19:00h. During both seasons the amount of time donkeys spent grazing between 19:00h and 20:00h reduced considerably.

Figure 5.8. Circadian distribution of oral behaviours exhibited by individual donkeys restricted to 8 hours grazing access per day

(a) Autumn (Aug – Sep)



(b) Summer (May – Jun)

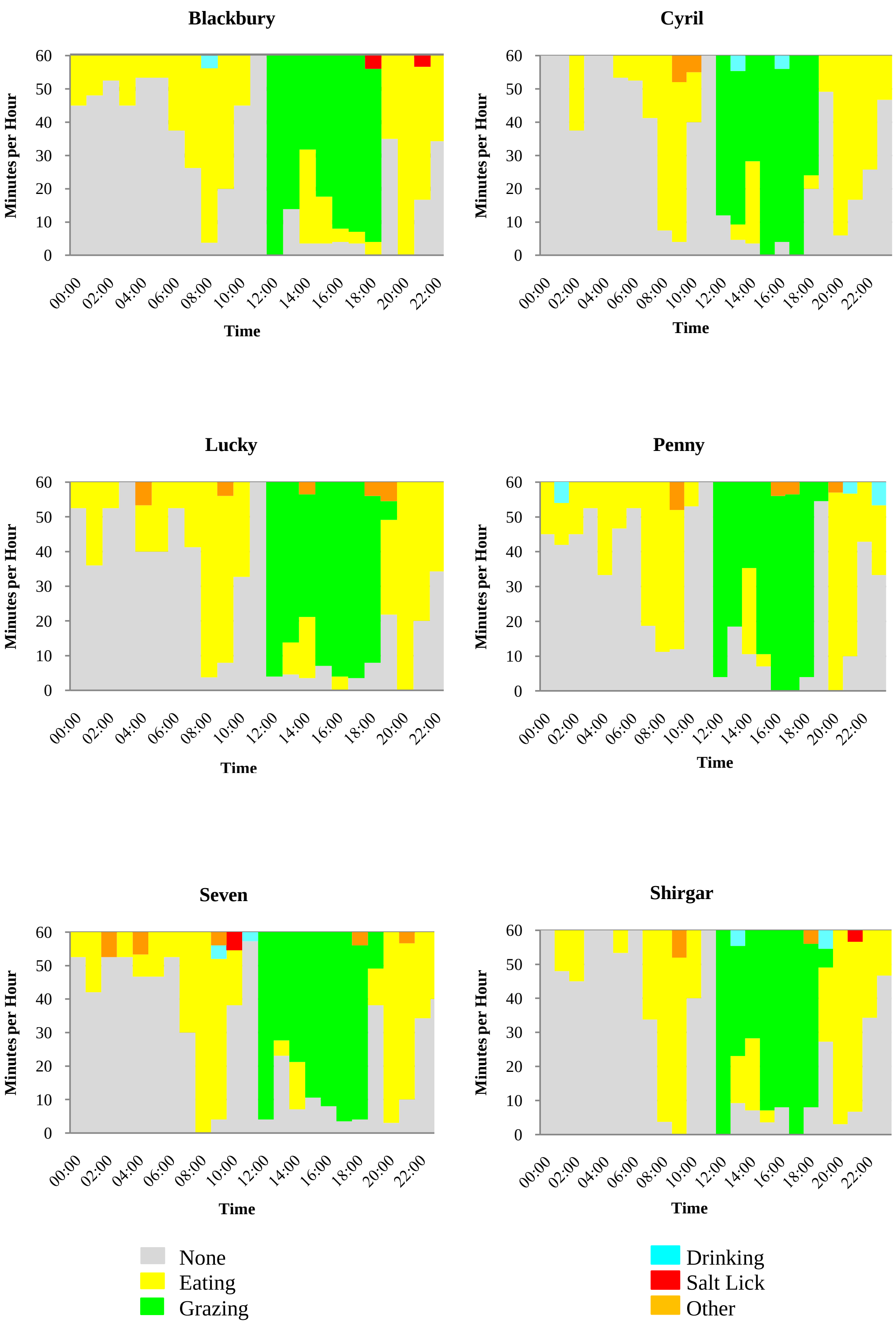
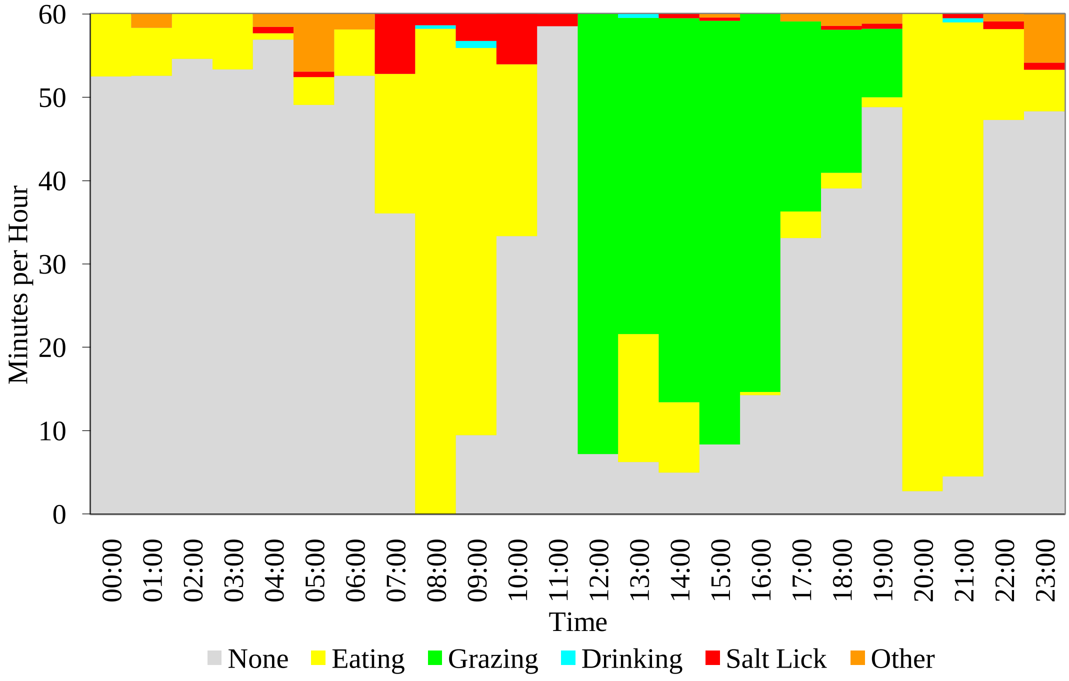
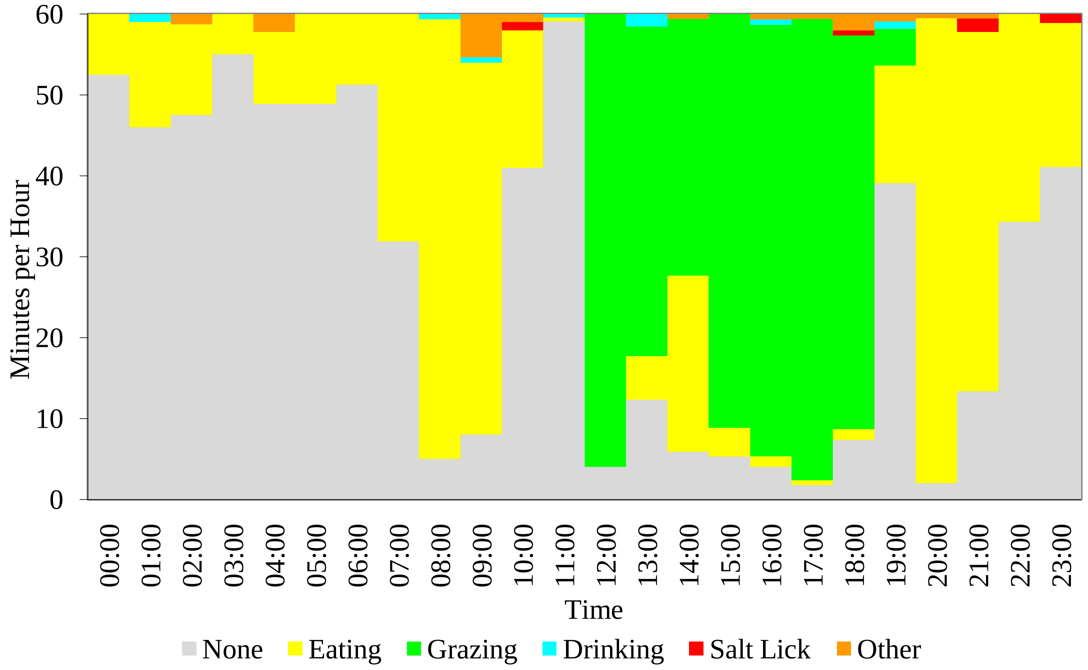


Figure 5.9. Mean circadian distribution of oral behaviours exhibited by all donkeys restricted to 8 hours grazing access per day

(a) Autumn (Aug – Sep)



(b) Summer (May – Jun)



12 Hour Grazing Group

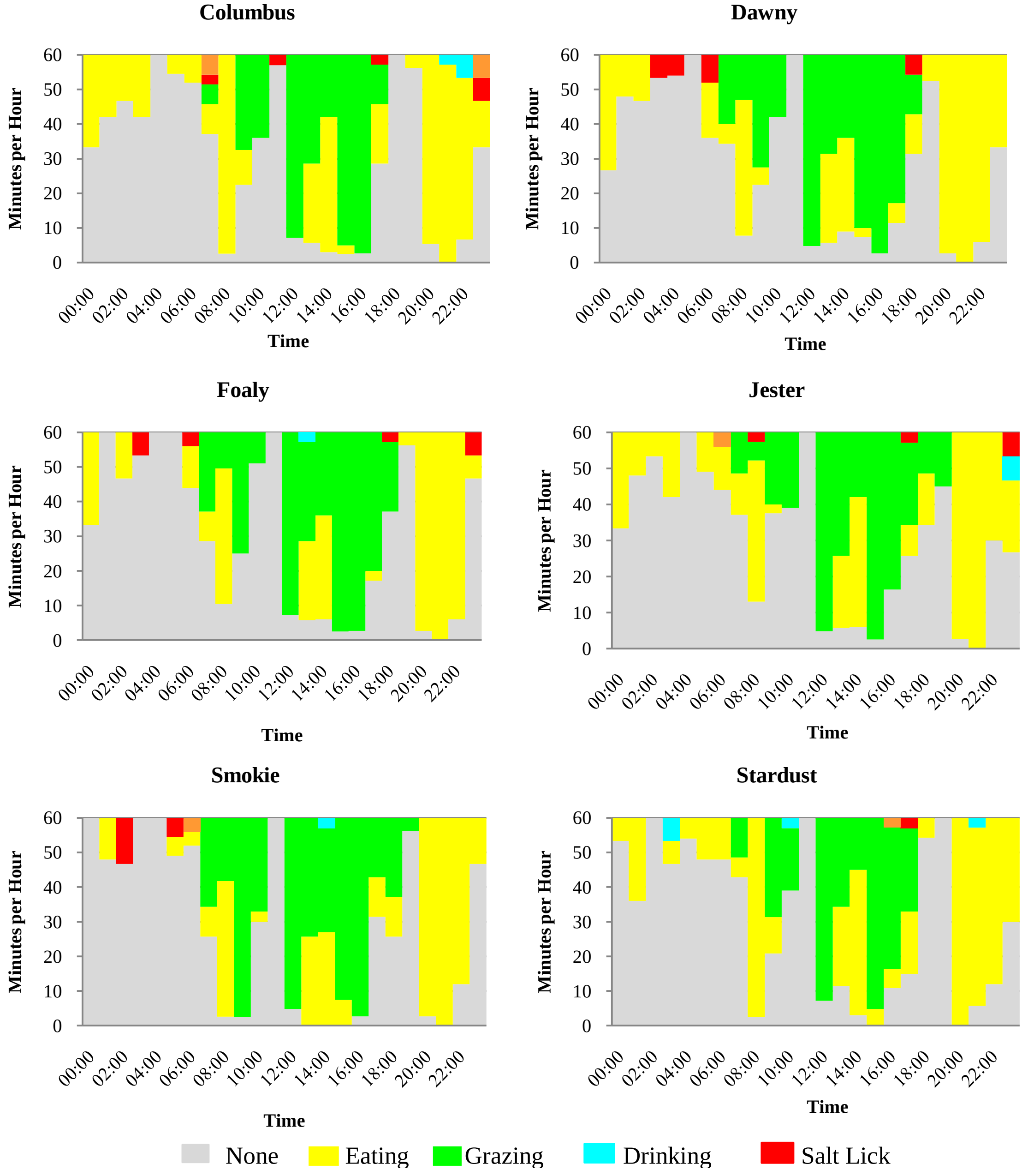
Circadian oral behaviours for individual donkeys restricted to 12 hours grazing per day are shown in Figure 5.10. Donkeys used in both seasons (Dawny, Foaly, Jester, Smokie and Stardust) generally spent more time grazing and less time eating straw during summer compared to during autumn. The longest daily grazing times during autumn and summer were recorded for Smokie (7:13h/day) and Sophie (7:51h/day), respectively. There was a clear trend in time spent eating straw compared to time spent grazing. Donkeys spending the most amount of time grazing generally spent the least amount of time eating straw, and vice versa. In autumn Columbus spent the least amount of time grazing at 4:01h/day, and 7:02h/day eating straw, second only to the 7:11h/day Stardust spent eating straw. In summer the trend continues with Dawny spending the least amount of time grazing (5:23h/day) and most amount of time eating straw (7:01h/day).

During both seasons donkeys restricted to 12 hours grazing access per day ate straw more frequently throughout the day, compared to donkeys restricted to 8 hours. Eating of straw continued throughout the night, although total time spent feeding (eating straw and grazing) by the group (all donkeys) during the night was less than that exhibited by donkeys in the 23 hour grazing group, but more than by those in the 8 hour group. The eating of straw coincided with the feeding of fresh straw, with donkeys in this grazing group spending longer eating straw during the day than those restricted to 8 hours grazing.

Of the total 12 hours available to graze donkeys spent 5:30h grazing during autumn and 6:42h grazing during summer, with 77 and 75% of this grazing activity occurring after fresh pasture was available, respectively (12:00h until 20:00h). Donkeys spent a similar amount of time drinking during both seasons, although donkeys drank more frequently during autumn than during summer, when drinking was observed only when the donkeys were rounded into the barn area prior to being stabled at 11:00h, and between 11:00h and 12:00h when donkeys were in their individual stables.

Figure 5.10. Circadian distribution of oral behaviours exhibited by individual donkeys restricted to 12 hours grazing access per day

(a) Autumn (Aug – Sep)



(b) Summer (May – Jun)

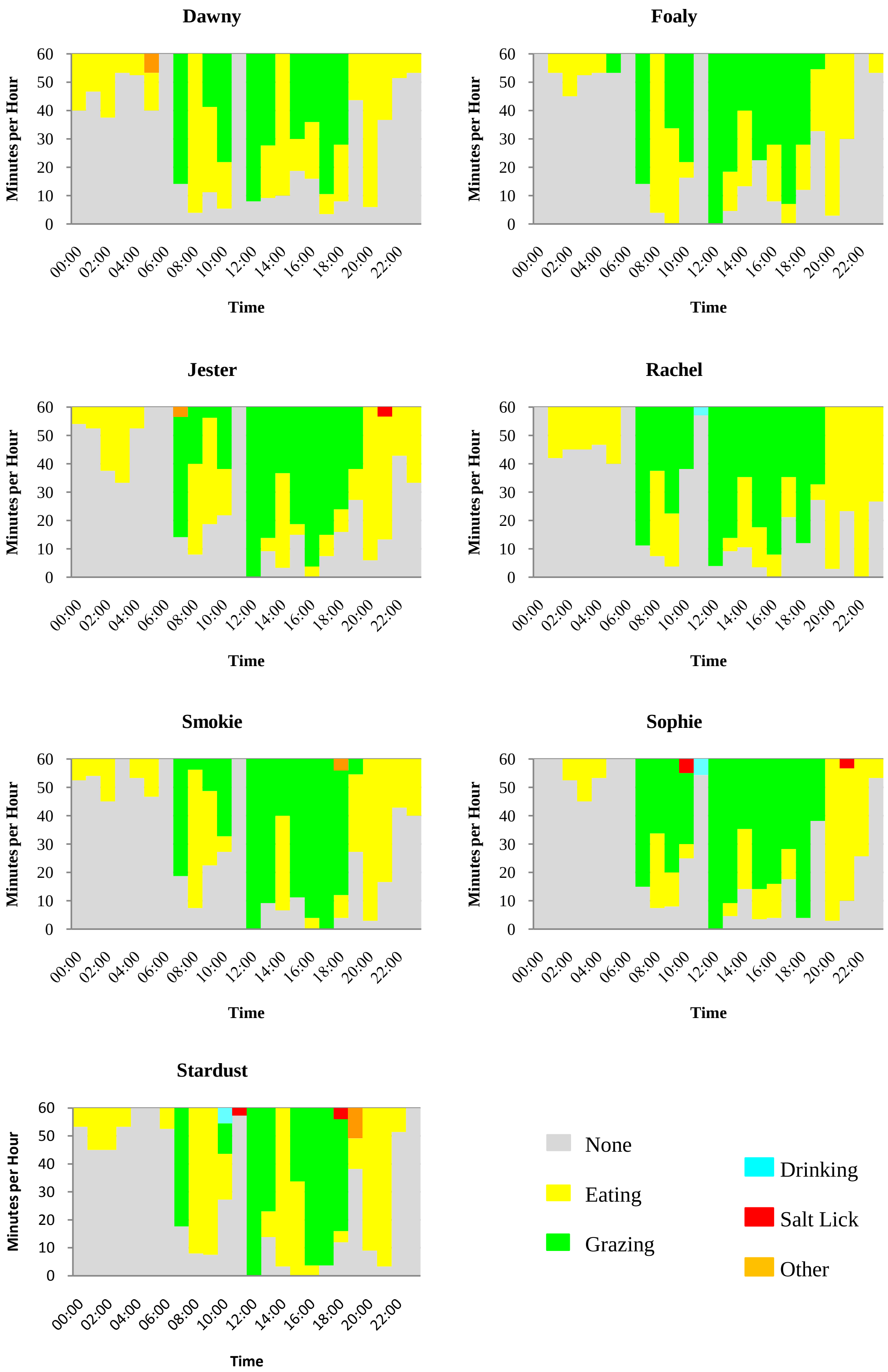
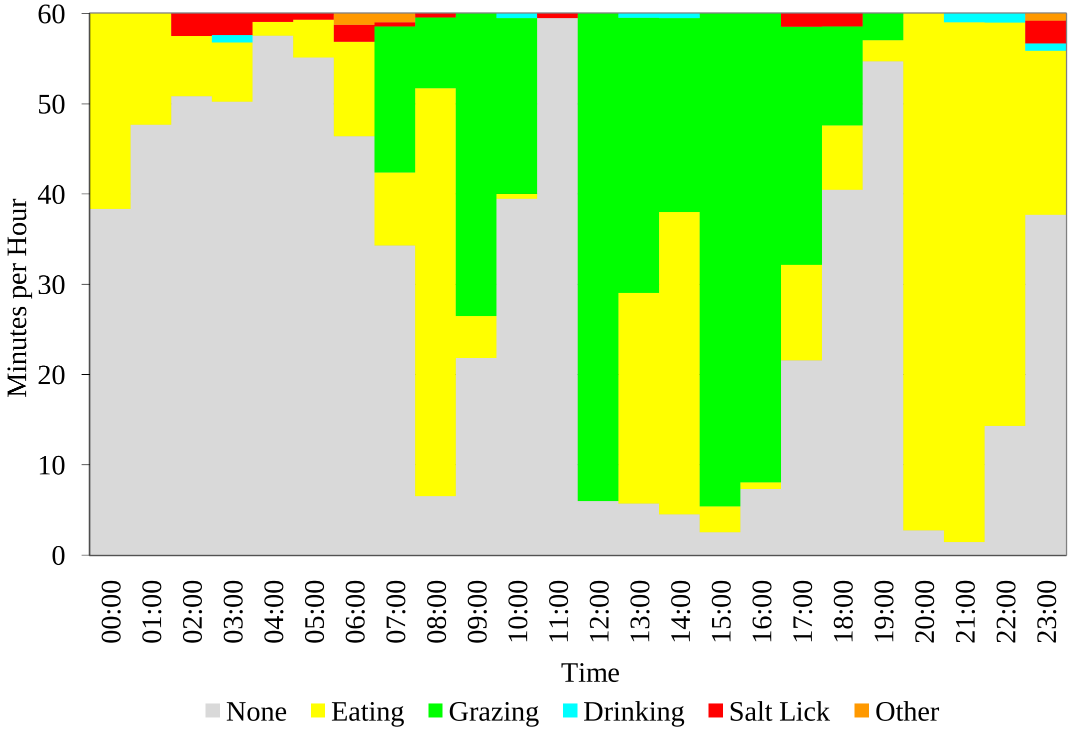
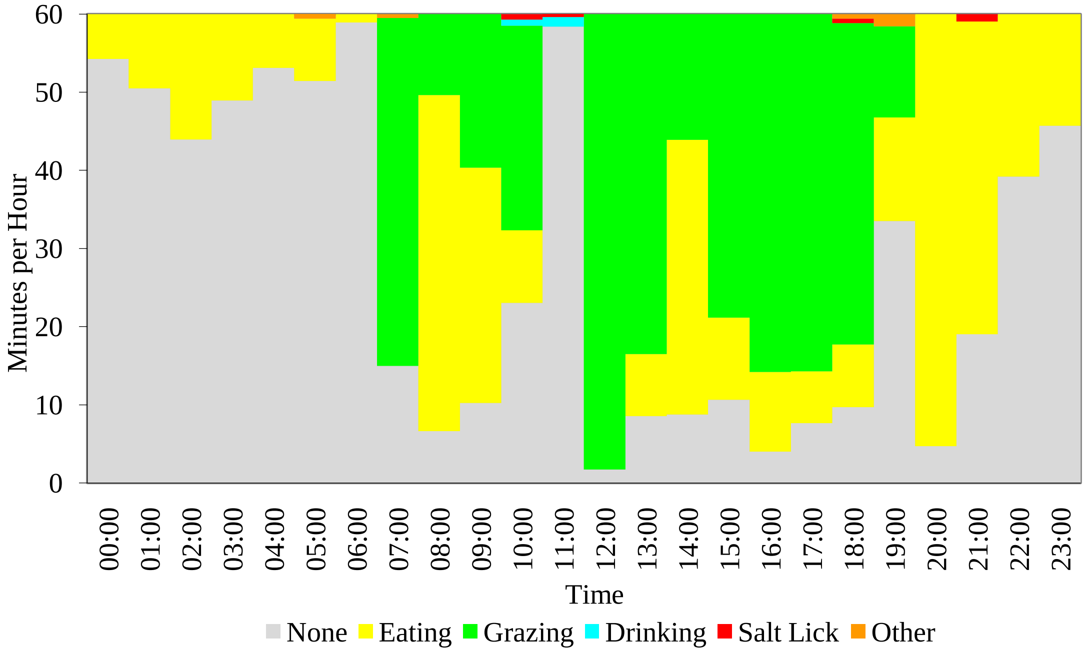


Figure 5.11. Mean circadian distribution of oral behaviours exhibited by all donkeys restricted to 12 hours grazing access per day

(a) Autumn (Aug – Sep)



(b) Summer (May – Jun)



23 Hour Grazing Group

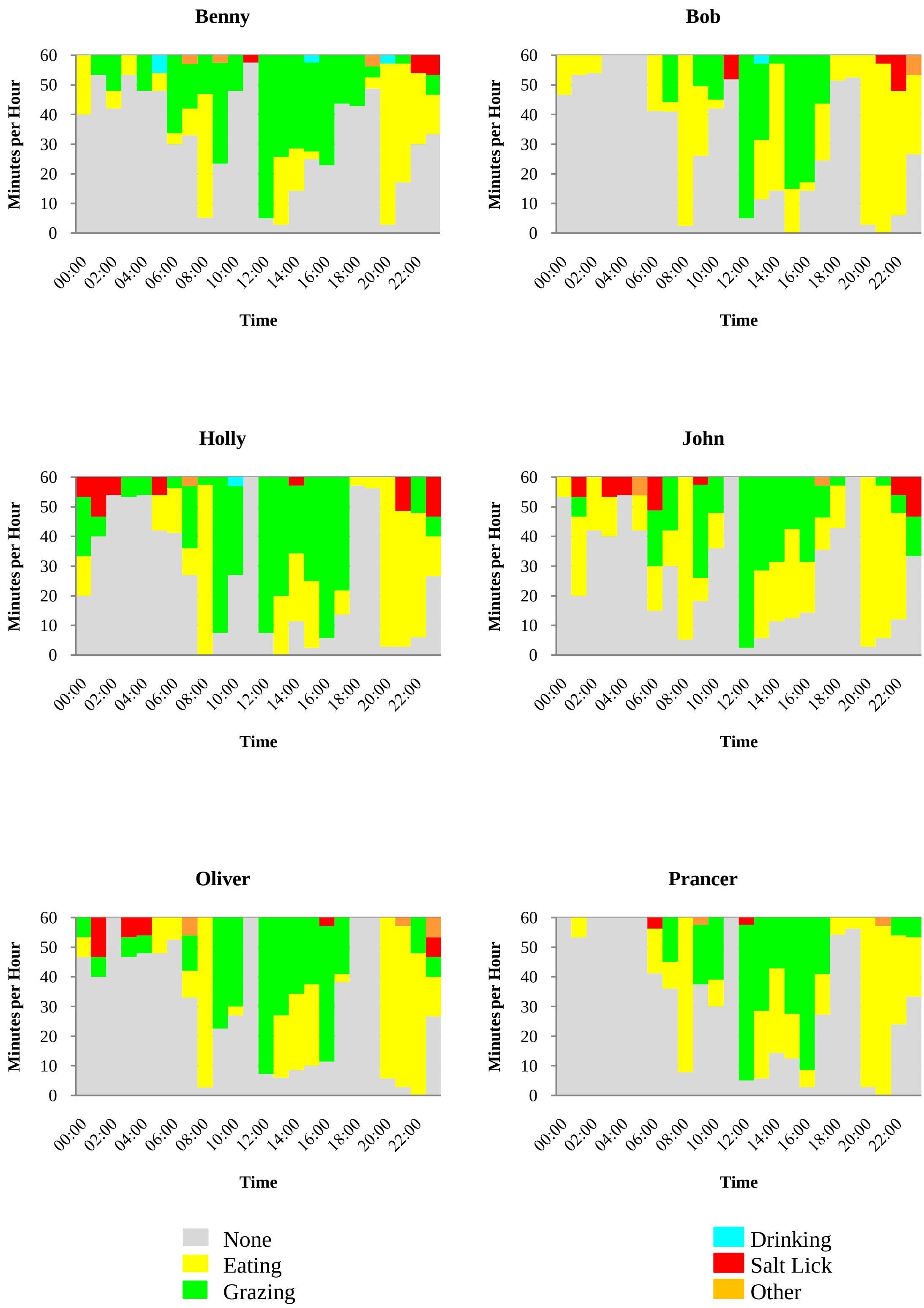
Individual donkey circadian oral behaviours are shown in Figure 5.12. The trend for longer grazing times and shorter eating (straw) times observed in the 12 hour grazing group was also observed for the 23 hour group during autumn and summer. In autumn Holly spent the most amount of time grazing at 8:00h/day, and 4:47h/day eating straw, second only to the 4:00h/day Benny spent eating straw. In summer however Holly spent the least amount of time grazing and longest time eating straw compared to all other donkeys in the group (5:09h and 8:21h/day respectively). Grass intake (kg/day) by Holly did not follow the same trend as grazing time. During autumn Holly ate an average of 0.46kg grass DM over 8:00h, compared to the 1.32kg grass DM over 5:09h during summer. The higher grass intake by Holly in summer was achieved through greater grazing intensity (bites per minute) resulting in a higher intake rate compared to during autumn.

The three shortest grazing times for the 23 hour group over both seasons were recorded for Bob, John and Prancer during autumn (3:29h, 4:05h and 5:00h, respectively). No night grazing (between 20:00h and 07:00h) was observed for Bob and Prancer in autumn, with only 45 and 48 minutes of grazing being recorded for Oliver and John respectively. An increase in night grazing was observed for all donkeys except Holly during summer, although the maximum increase in night grazing time was observed in John at 38 minutes. All donkeys, except Holly, grazed for longer during summer between 07:00h and 20:00h, increasing total grazing time per day in summer compared to autumn.

Circadian oral behaviours for all donkeys in the 23 hour group are shown in Figure 5.13. In both seasons donkeys spent more time grazing between 07:00h and 19:00h, coinciding with when other donkeys were also allowed grazing access (Figure 5.13). Eating straw was also observed throughout the day and night, although less time was spent eating from 00:00h until 07:00h. The eating of straw coincided with the feeding of fresh straw, with donkeys in the 23 hour group spending more time eating straw in the afternoon from 13:00h until 16:00h than donkeys in any other grazing group. Of the total time donkeys were permitted to graze, donkeys in the 23 hour group spent 5:20h grazing and 5:55h eating straw during autumn, with 86% of this grazing behaviour occurring when other donkeys were also able to graze (07:00h – 11:00h and 12:00h – 20:00h). During summer the same donkeys spent more time feeding per day, increasing the time spent eating by 18% (total eating time 6:42h) and grazing by 4% (total grazing time 5:42h), although only 66% of grazing behaviour occurred when other donkeys were also able to graze. The use of salt licks was more common during the evening and night during autumn. The salt licks were available inside stables freely accessible to the donkeys in the 23 hour group (stables acted as shelter). Thus the increased use of salt licks during the night was probably a result of the donkeys being in closer proximity to the salt licks during the night than during the day, resulting in increased usage. This pattern, however, was not repeated during summer when the same management system was followed.

Figure 5.12. Circadian distribution of oral behaviours exhibited by individual donkeys restricted to 23 hours grazing access per day

(a) Autumn (Aug – Sep)



(b) Summer (May – Jun)

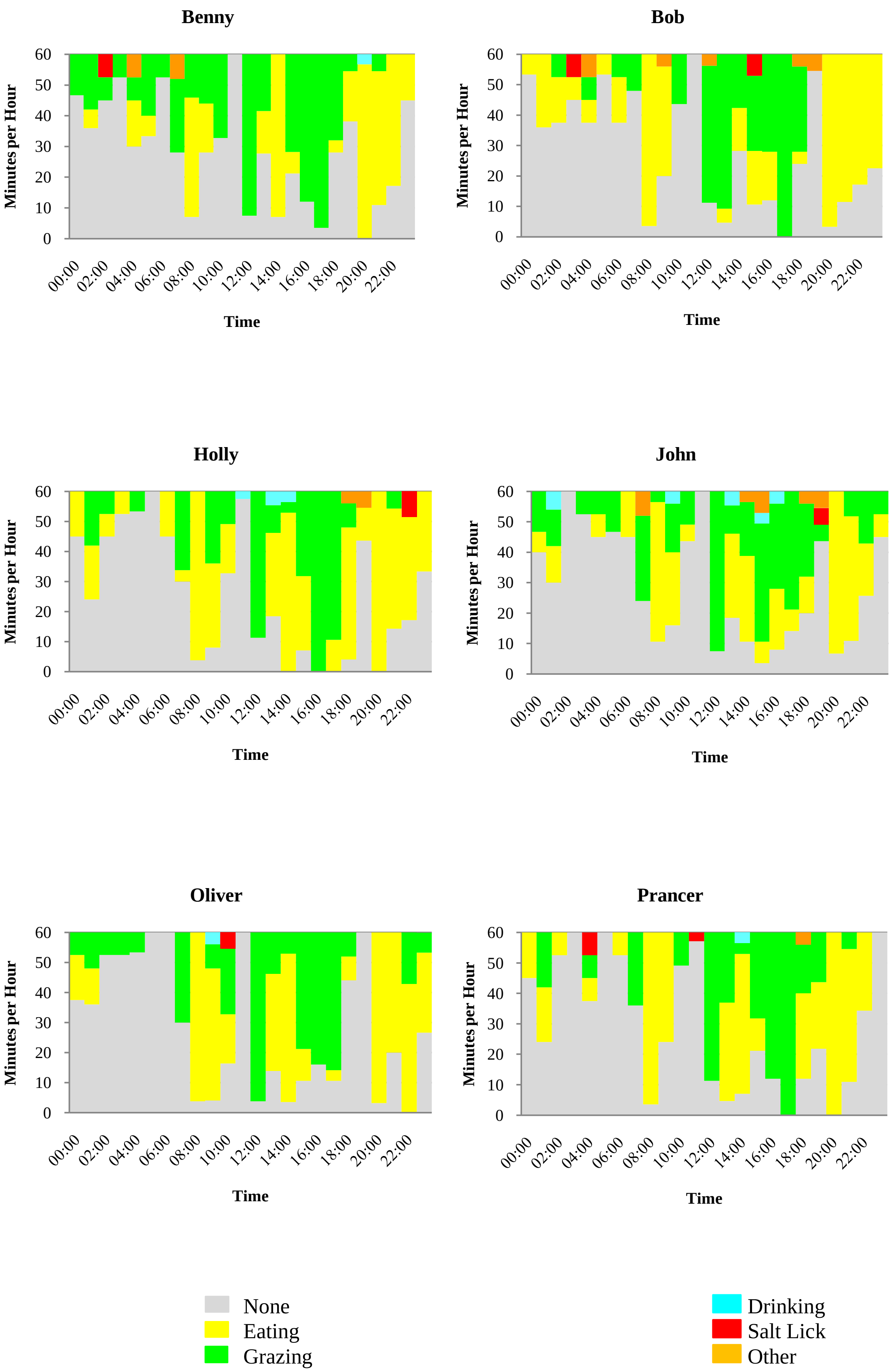
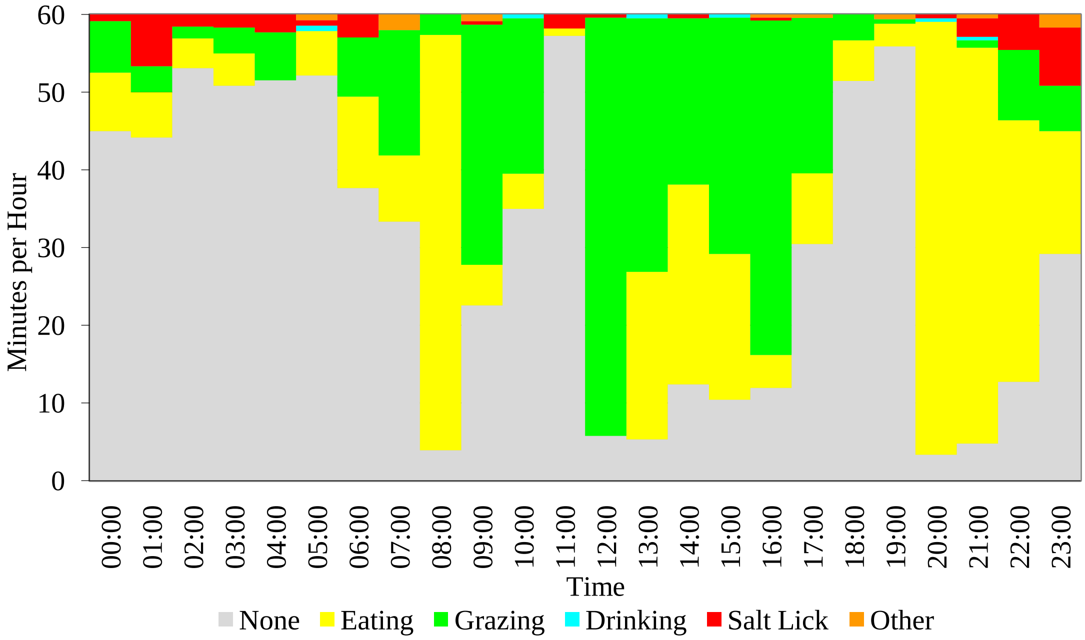
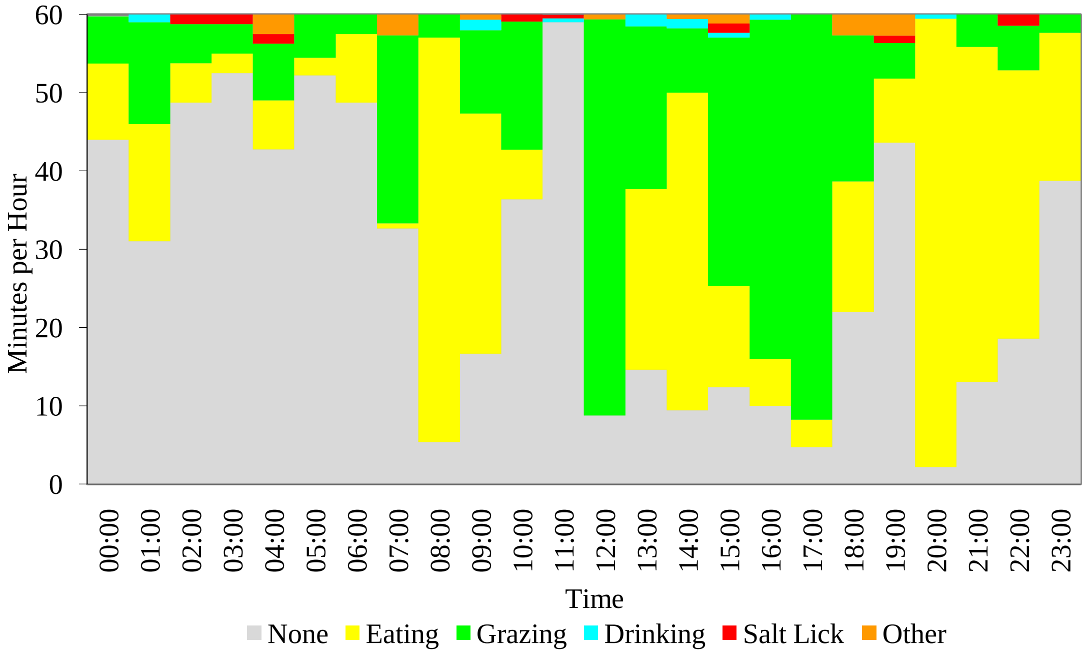


Figure 5.13. Mean circadian distribution of oral behaviours exhibited by all donkeys restricted to 23 hours grazing access per day

(a) Autumn (Aug – Sep)



(b) Summer (May – Jun)



5.5 DISCUSSION

5.5.1 Food Offered

Previous studies have shown that horses (Archer, 1973) and donkeys (Rutagwenda *et al*., 1990; Lamoot *et al*., 2005) select fibrous foods even when more nutritious, low fibre foods are available, indicating that equids have a requirement for fibrous foods within their diet. The feeding of barley straw in the present study provided the donkeys with a source of poorly digestible fibre. The grazing pasture provided a more digestible source of energy and CP, with the autumn pasture being of greater nutritional quality than the summer pasture. The autumn experimental period coincided with autumn grass growth, indicated by the better quality and lower herbage mass of the autumn pasture. Pasture during the summer experimental period was at later growth stage providing greater herbage mass but lower levels of CP.

During both seasons the strip of fresh pasture was grazed down to ground level within approximately 30 minutes of being available to the donkeys. Previously grazed pasture in the remainder of the field was grazed close to the ground (within 1 – 2cm of soil level), with no visible growth during both seasons. Despite this apparent lack of grass in the field after the donkeys had consumed the fresh pasture strip, grazing continued to occupy the donkeys for a considerable proportion of their grazing time.

5.5.2 Food Intake

The aims of the study were to determine the daily DMI of grazing donkeys and to assess for any effects of season and grazing time on diet composition and intake. At present there are no published values for DMI of grazing donkeys in the UK. The only study reporting intake by grazing donkeys is that of Smith (1999), reporting

DMI by donkeys in Zimbabwe. Donkeys with 23 hours grazing access consumed approximately 4.00kg DM per day (90g/kg $BW^{0.75}$) during the dry season, and 4.18kg per day (85g/kg $BW^{0.75}$) during the wet season (Smith, 1999). Mean DMI by donkeys with 23 hours grazing access in the present study were considerably lower, at 3.09kg DM per day (58g/kg $BW^{0.75}$) in summer and 2.61kg DM per day (49g/kg $BW^{0.75}$) in autumn. The lower intakes by the donkeys in the present study were probably due to differences in quality of the pasture available. The pasture in the Zimbabwe study was of poorer quality in both the wet and dry seasons than that grazed by the donkeys in the current study. The Zimbabwe pasture was higher in fibre (NDF 875 – 920g/kg DM) and lower in CP content (CP 31 – 68g/kg DM) than the autumn and summer grazing in the current study (677 and 569g NDF/kg DM, and 125 and 67g CP/kg DM for autumn and summer respectively, Table 5.2). The pasture available to the donkeys in the Zimbabwe study was of similar nutritional quality to the barley straw fed in the present study (888 and 806g NDF/kg DM, and 33 and 28g CP/kg DM for autumn and summer respectively, Table 5.2).

Comparisons of DMI (per day and on a metabolic body weight basis) by the donkeys when grazing with when they were housed (Chapter 4) show similar intakes during autumn, but higher intakes during summer. When housed, DMI in summer was on average 2.32kg per day (47g/kg $BW^{0.75}$). Dry matter intakes when grazing in summer ranged from 2.51 – 3.09kg per day (55 – 58g/kg $BW^{0.75}$). The higher intakes in summer, when herbage mass was greater, suggest that as food becomes more available, food intake increases, with the likelihood of becoming overweight also increasing.

Compared to results from previous studies on housed donkeys fed *ad libitum*, DMI by donkeys in the present study were considerably lower. In the studies shown in Table 2.4 (Chapter 2), donkeys consumed on average 72g/kg $BW^{0.75}$. Intakes of straw diets in these previous studies averaged 58g/kg $BW^{0.75}$, similar to those reported in the present study during summer. The similarity in food intakes was due to the high straw content of the diets consumed by the donkeys during both autumn and summer. Despite DMI by the donkeys in the present study being lower than the average reported in previous studies, but higher than those by the same donkeys in summer when housed, body weights of donkeys in all three grazing groups remained stable ($\pm$ 5kg of start weight) during both seasons (mean body weight: autumn 181.2kg, summer 182.1kg). The maintenance of body weight by donkeys in the present study shows the donkeys were in energy balance, although DEI's were higher than the maintenance requirements determined in Chapter 4. Maintenance DE requirements during all seasons, except winter, ranged from 0.30 - 0.34 MJ/kg $BW^{0.75}$. Energy intakes, on a metabolic body weight basis, by the donkeys in the present study, ranged from 0.37 – 0.44 and 0.32 – 0.41MJ during autumn and summer, respectively. The higher energy intakes by the donkeys in the present study are probably due to an additional energy cost involved in foraging and daily activity. Using the maintenance requirements of each donkey when housed, the additional energy cost of daily activity and grazing for each donkey was calculated as the difference between daily maintenance DEI and daily DEI when grazing. The mean daily energy expense of grazing for each grazing group is shown in Table 5.4.

The energy cost of activity and grazing in donkeys has not been previously reported. A study of energy expenditure by grazing yearling horses in Japan found the energy expended during grazing activity was 4.2MJ per hour (Asai *et al*., 1999). From Table 5.4 and feeding behaviour data showing donkeys grazed for a minimum of 4:42h per day, it is evident that the additional energy requirements of grazing activity by donkeys in the present study were considerably less than those of horses in the study by Asai *et al*. (1999). The lower energy expenditure by the donkeys during grazing and normal activities supports previous findings that donkeys are more efficient at walking than horses (Pearson *et al*., 1998), reducing the energy cost of grazing (Osuji, 1974), however, further research is required to substantiate such findings.

Table 5.4. Estimated mean daily digestible energy (DE) expense of grazing activity of donkeys with 8, 12 and 23 hours grazing access during autumn and summer calculated from DE intake and maintenance DE requirements (MJ/kg BW$^{0.75}$/day)

Grazing Hours	Autumn				Summer			
	DEI	DE req. M	Activity Energy Expense		DEI	DE req. M	Activity Energy Expense	
			/kg BW$^{0.75}$/day	/day			/kg BW$^{0.75}$/day	/day
8	0.39	0.32	0.07	3.5	0.41	0.36	0.05	2.7
12	0.44	0.28	0.16	5.4	0.32	0.30	0.02	0.8
23	0.37	0.30	0.07	3.7	0.36	0.33	0.03	1.4

DE req. M: Maintenance DE requirements

Effect of Season

Season significantly affected food intake with donkeys in the 8 and 23 hour grazing groups eating more during summer when pasture availability was greater. Digestible energy intakes, however, were similar during autumn and summer, due to the lower quality of the summer pasture. Donkeys responded to the poorer quality summer pasture by grazing more intensively but less selectively, increasing the rate at which food was consumed, resulting in higher pasture and total food intakes. This response to pasture quality and availability has been previously reported for yearling horses grazing temperate pastures in Australia (Friend & Nash, 2000). Janis (1976) proposed that equids respond to decreasing diet quality by increasing intake, at the expense of digestive efficiency. Results from the Australian and present study support this view, although the effect of higher food intake on DMD in the present study is masked by the higher grass content of the summer diets (Figure 5.4).

The higher grass content of the summer diets consumed by the donkeys shows that as herbage mass increases donkeys increase their pasture intake. This finding is opposite to that reported for horses grazing pastures at the same growth stage but of different herbage mass in Queensland, Australia, where herbage mass had no effect on daily pasture intakes (McMeniman, 2003). The lack of effect of herbage mass in the previous study may have been due to an ample supply of pasture, even at the lower herbage mass. Herbage mass ranged from 445 – 594g DM/m^2, equating to a grazing area containing 2000 – 2671kg DM per horse. In contrast, herbage mass in the present study was considerably lower during both seasons. The fresh pasture strip equated to 138g DM per donkey per day in autumn, and 296g DM per donkey per day in summer. In addition, pasture availability in the remainder of the field was considerably lower, especially in autumn, significantly reducing DMI during this season.

From the short time in which the donkeys consumed the fresh pasture, and the low herbage mass of the pasture in the remainder of the field, combined with the high level of straw in the diets, it is concluded that the donkeys in this study on this pasture would have been unable to satisfy maintenance energy requirements or appetite, on pasture alone. It is therefore not possible to determine if donkeys regulate their pasture intake in response to their energy requirements. Maintenance of stable body weights during both seasons show that when fed poor quality forage, and when grazing pasture of limited availability, donkeys did not consume energy in excess, however, further work is needed to determine if donkeys regulate their intake when grazing more ample pastures.

Effect of Grazing Time

Restricting grazing access time is a method frequently used by horse, pony and donkey owners in the UK to limit daily DMI, under the assumption that limiting the time available to graze will reduce the amount of pasture, and thus, total amount of food consumed. Mean DM and DE intakes did not differ significantly between grazing groups during either season, although there was a general trend of higher food intakes as grazing time increased. This trend, however, appears to be influenced by pasture availability. The greater pasture availability in summer enabled the donkeys with only 8 hours grazing access per day to compensate for shorter grazing times by grazing more intensively throughout their pasture access time. The number of bites per minute was higher at 16:00h during summer, compared to during autumn, by donkeys in all grazing groups, showing the available pasture in the remainder of the field was greater during summer. This higher herbage mass enabled donkeys in the 8 hour group to maintain pasture intake throughout their period of grazing access, resulting in a similar grass intake as donkeys with 12 hours grazing access and same DMI, proportional to metabolic body weight, as donkeys with 23 hours access. Results therefore indicate that when pasture is sparse, limiting grazing time to 8 hours will help to reduce total food intake but that when pasture is more abundant grazing times would need to be less than 8 hours to reduce food intake and prevent donkeys compensating for shorter pasture access times.

The combined effects of grazing time and pasture availability suggest that the donkeys compensated for changes in pasture access and herbage mass by adjusting their pasture intake. However, analysis of diet composition shows this was not necessarily the case and that the donkeys compensated for shorter grazing times by consuming more straw.

5.5.3 Diet Composition

The finding that all donkeys selected to eat more straw than grass during both seasons reflects the low herbage mass available per donkey during both autumn and summer, and the inability of a pasture only diet to satisfy energy requirements and DMI. The high straw intake may also reflect a necessity for fibrous foods within the diet of the donkey, as proposed by Lamoot *et al.* (2005) after donkeys were observed to consume fibrous plants when plants of greater nutritional value were also available. In support of this view are the findings that donkeys consumed similar amounts of NDF during both seasons, regardless of differences in diet composition and total DMI. Donkeys consumed 1.52 – 2.80kg NDF per day in autumn (mean 2.11kg) and 1.32 – 2.96kg NDF per day in summer (mean 2.07kg).

Season significantly affected diet composition by influencing the quantity and proportion of grass consumed by the donkeys. The higher grass intakes in summer by donkeys in all grazing groups support the view that as pasture availability increases, donkeys increase their pasture intake. The effect of grazing time in summer also supports this view, with donkeys in the 23 hour group consuming significantly more grass per day than donkeys with 12 hours or less grazing access. It could be assumed that the higher grass intakes by donkeys in the 23 hour group were due to donkeys grazing for longer each day. However, behaviour results show donkeys grazed for similar lengths of time each day when managed with 8 (5:46h) and 23 (5:42h) hours grazing access (Figure 5.7). The longest grazing times were recorded for donkeys with 12 hours daily pasture access (6:42h). Despite spending significantly more time grazing, donkeys in the 12 hour group consumed the least amount of grass (Figure 5.4). These differences in grass intake can be explained by differences in grazing intensity. During summer, donkeys grazed more intensively at 16:00h compared to 12:15h (Figure 5.5), although the higher herbage mass of the fresh ungrazed pasture would have increased intake rate during the 12:15h observation period due to donkeys being able to take larger bites. Donkeys in the 23 hour group took the most bites per minute (28 bites/minute) compared to those in the other grazing groups (8 hour group - 21bites/minute, 12 hour group - 23 bites/minute) during the 12:15h observation period. This greater intensity with which the 23 hour group donkeys grazed would have increased intake rate and reduced the amount of fresh pasture available to donkeys in the other grazing groups, potentially reducing total pasture intake by donkeys in the 12 and 8 hour groups. Donkeys restricted to 8 hours grazing access did compensate for shorter grazing access time by increasing their grazing intensity at 16:00h (39 bites/minute), however, the lower pasture availability in the remainder of the field, compared to the fresh pasture strip, would have limited the amount of grass able to be consumed by the donkeys, resulting in a lower grass intake by the 8 hour group compared to the 23 hour group, but higher intakes compared to the 12 hour group.

As would be expected, the donkeys' diets comprised of significantly less grass in autumn when pasture availability was lower. An unexpected result during autumn was the lower grass intake by the donkeys in the 23 hour group compared to those in the 12 and 8 hour groups, despite the 23 hour donkeys (5:18h) grazing for longer than the 8 hour group (4:42h) and for a similar length of time as the 12 hour group (5:30h) (Figure 5.7). The lower grass intake by the 23 hour group was the result of two donkeys in the group eating considerably less grass (0.09 and 0.10kg grass DM/day for John and Bob respectively) than all other donkeys during autumn (0.24 – 0.65kg grass DM/day). Removal of Bob and John from the 23 hour group resulted in a mean grass intake for the 23 hour group of 0.38kg grass DM/day, similar to grass intakes by the 8 and 12 hour groups ($P>0.05$).

5.5.4 Feeding Behaviour

Previous studies have reported different time periods allocated to feeding by horses (Table 5.5). Total feeding time during summer by grazing Przewalski horses in Germany averaged 7:30h per day (Berger *et al*., 1999), less than that recorded for Przewalski horses in Virginia (11:08h) (Boyd, Carbonaro & Houpt, 1988) and for growing Mulassier Poitevin horses grazing wetlands in western France (12:58h) (Menard *et al*., 2002). Time allocated to feeding in autumn was longer than that during summer in the German ($P>0.05$) and French ($P<0.001$) studies, averaging 7:47h and 16:19h respectively. Daily feeding time by grazing donkeys has only been recorded in one study. Smith (1999) reported feeding times for donkeys grazing in Zimbabwe of 13:34h per day at the end of the dry season and of 17:00h per day during the wet season, when grazing was of better nutritional quality. During both these observation periods donkeys had 23 hours grazing access per day. Donkeys in the present study spent between 10:18h and 12:42h feeding per day. The slightly lower feeding times by donkeys in the present study are likely to be due to the better quality of the pasture in the present study compared to that available to donkeys in Zimbabwe. From these results it would appear that donkeys devote similar periods of time to feeding as do horses.

Table 5.5. Total daily feeding time (hours/day) by horses during summer and autumn

Animal (*n*)	**Location**	**Season**	**Daily feeding time (hours/day)**	**Reference**
Przewalski horses (4)	Germany	Summer	7:30	Berger *et al.* 1999
		Autumn	7:47	
Mulassier Poitevin horses (2 – 4)	France	Summer	12:58	Menard *et al.* 2002
		Autumn	16:19	
Przewalski horses (8)	Virginia, USA	Summer	11:08	Boyd, Carbonaro & Houpt, 1988

n: Number of animals

Circadian distribution of feeding activity by the donkeys in the present study was also similar to that previously reported for horses, with the majority of feeding occurring during daylight hours (Doreau, Martin-Rosset & Petit, 1980). Night feeding was observed by donkeys in all grazing groups, although to lesser extent than during the day. Night grazing by most (4 out of 6 in autumn) donkeys with 23 hours pasture access was observed, although eating straw was the preferred night feeding activity. The lower frequency with which donkeys grazed at night is likely due to the donkeys in the 23 hour group seeking the companionship of the donkeys in the other grazing groups that were restricted to the yard and barn areas throughout the night.

The higher frequency with which donkeys in the 23 hour group grazed during the day, when other donkeys were also grazing, supports this view.

Effect of Season and Grazing Access Time on Feeding Behaviour

Total feeding time and time spent grazing were affected by season. Donkeys in all grazing groups spent longer grazing during summer, resulting in longer total feeding times, compared to during autumn. Donkeys spent a similar length of time eating straw regardless of the time spent grazing, grazing group or season (5:35h – 6:20h in autumn, 6:01h – 6:44h in summer). The finding that donkeys grazed for longer in summer is opposite to previous findings reported for grazing behaviour in horses. Berger *et al*. (1999), Menard *et al*. (2002) and Lamoot and Hoffman (2004) reported the shortest grazing periods during summer in domestic and semi-wild horses grazing temperate pastures. In the latter two studies the shorter grazing times coincided with intake of a more nutritious diet. In the present study grazing time was also shorter when pasture was of greater nutritional value (autumn). The shorter grazing times in autumn may also be a response to the considerably lower availability of the pasture in autumn compared to during summer. It is proposed that if the donkeys had grazed for longer in autumn, the energy expended during these longer grazing periods would have been greater than that gained from pasture intake, resulting in a negative energy balance. In replacement of grazing activity, the donkeys satisfied energy requirements by increasing their intake of straw, a readily available food source, without the need to expend energy walking, searching and selecting for suitable plant species or plant parts. Similarity in grazing times between grazing groups during autumn agree with this proposed response to lower pasture availability. Differences in grazing access times did not influence time allocated to grazing, indicating that there was no nutritional or energy benefit in grazing for longer, due to the low herbage mass of the available pasture.

Grazing group influenced distribution of grazing activity throughout the day. When restricted to only 8 hours pasture access per day grazing was the most frequently recorded activity during this time with donkeys spending 55% of the 8 hours actively grazing. This result supports previous observations of donkeys with 8 hours grazing access in Ghana, where donkeys grazed almost continuously (Canacoo & Avornyo, 1998). In such circumstances, restricting pasture access time may prompt donkeys to gorge on pasture when allowed to graze, increasing the likelihood of donkeys suffering pasture induced laminitis. In the present study the low herbage mass of the remainder of the field in both seasons prevented such a response, although results from the same group of donkeys in summer show how as pasture availability increased, donkeys extended their grazing times. During summer donkeys in the 8 hour group spent on average 72% of their pasture access time actively grazing, equating to an increase in grazing time of 1 hour. Although grazing for similar lengths of time in autumn as donkeys in the 8 hour group, donkeys in the 12 and 23 hour grazing groups distributed their grazing activity over much longer periods of time (Figure 5.8 – 5.11), reducing the rate at which grass was consumed. During summer donkeys in the 12 hour grazing group spent significantly more time grazing per day than those in the 8 and 23 hour groups, although time spent eating straw was not affected.

From the results of this study it appears that restricting grazing time does not significantly reduce pasture intake or total daily food intake by donkeys due to more efficient utilisation of their grazing time, by spending the majority of their time actively grazing and consuming additional forage sources (straw) when grazing was not possible. In addition, restricting grazing time may actually promote increased grazing activity.

5.6 CONCLUSIONS

Daily food intakes by donkeys in this study were lower than has been previously reported for grazing and housed donkeys, but are similar to the intakes reported for the same donkeys when housed. The similarity in intakes by the donkeys when managed under two different husbandry systems indicates that the daily food intakes reported here are representative of the daily appetite of this group of donkeys, and that this was not affected by grazing access. Further research, however, is needed to confirm these lower intakes in other donkeys and to determine the daily food intake by grazing donkeys with access to more abundant pastures.

Further research is also required to determine if donkeys regulate their intake of grass when grazing access is continuous and when restricted. The circannual rhythm of body weight, demonstrated by wild and semi-wild horse populations (Scheibe & Streich, 2003; Berger *et al*., 1999), indicates that throughout the summer equids increase their food and energy intake to increase body fat reserves in preparation for reduced food availability and quality and loss of body weight, in winter. Daily DM and grass intakes by the donkeys in this study increased in summer compared to autumn, indicating that the donkeys were exhibiting the same circannual behaviour as reported for horses. Body weight measurements however were stable throughout each recording period and were similar during summer and autumn. These results indicated that donkeys regulate their total daily energy intake to satisfy requirements. If this is the case, and grazing ceases when energy requirements are satisfied, then restricting grazing time offers little benefit to the management of pasture intake unless aiming to reduce a donkey's body weight. If donkeys do not regulate their grass intake, grazing donkeys on pasture of low herbage mass or restricting them to less than 8 hours grazing per day, may help to reduce the amount of grass consumed, helping to manage food intake. The feeding of straw may also help to reduce pasture intake. Although not conclusive, results obtained in the present study indicate donkeys will consume preserved forages when offered alongside access to pasture, although it is uncertain if this behaviour would continue when diet composition is not limited by pasture availability, as appears to be the case here.

5.6.1 Future Work

Future studies of intake by grazing donkeys should focus on the effects of continuous and restricted grazing times on grass and total DM intake, when grass intake is not limited by low herbage mass. Removing the restrictive effect of low herbage mass would enable assessment of the mechanisms donkeys employ to regulate intake, particularly if intake is regulated to meet energy demands as is indicated in this study.

Further studies into the affects of different management routines on grass and daily intake are also needed. Strip grazing and set stocking grazing systems were identified in the Chapter 3 as common methods used to manage donkeys grazing access. Assessment of the effects of these two grazing systems would further increase the practical application of feeding guidelines formulated for donkeys.

CHAPTER 6

THE EFFECT OF SET STOCKING AND STRIP GRAZING ON DRY MATTER INTAKE BY GRAZING DONKEYS IN DIFFERENT SEASONS

6.1 INTRODUCTION

The donkeys used in Chapter 5 consumed less DM per day than has previously been reported for grazing and housed donkeys. Results also indicated that donkeys regulate their daily food intake to satisfy maintenance energy requirements. Application of these results to other groups of donkeys, however, is difficult due to the influence of pasture availability on results. Further research is therefore needed to confirm these results.

The influence of strip grazing and set stocking, grazing systems commonly used by donkey owners, on food intake and diet selection must be assessed in order to gain a more comprehensive understanding of how different husbandry practices affect the feeding behaviour of donkeys and enable feeding guidelines to be applicable to as many donkeys as possible.

Strip grazing is used to manage an animal's daily intake of fresh pasture and is observed to be common practice amongst horse, pony and donkey owners in the UK (personal observation). Although the availability of fresh ungrazed pasture can be monitored, the effectiveness of strip grazing in restricting total daily grass intake is unknown due to intake of grass from the remainder of the grazing area. Set stocking is the practice of allowing a fixed number of animals to graze a fixed area of pasture continuously for a long period of time (Brockman, 1998). The continuous grazing of pasture and inability to undertake pasture management activities due to the presence of animals on the land, reduces the popularity of this system for managing some livestock species. In contrast, this system is used frequently for managing horses and ponies. Results from the donkey survey (Chapter 3) indicate that many donkey owners use a combination of set stocking and rotational grazing systems, grazing their donkeys on fixed areas of land for varying lengths of time. Pasture intake by animals managed using the set stocking grazing system is primarily influenced by the availability and quality of pasture, thus grass intake should follow the seasonal pattern of pasture availability. If this is the case, grass intake should be highest in spring and early summer and lowest in winter, resulting in a respective increase then decrease in body weight.

The benefits of either of these systems in managing grass intake and body weight changes in horses or donkeys have not previously been investigated. Recommended grazing areas for donkeys when using the set stocking system are considerably less than for horses (1 ha/horse) (Pilliner, 1992) at approximately 0.02 – 0.03 ha per donkey (Personal Communication; Faith Burden, The Donkey Sanctuary, UK). The suitability of this recommendation for managing grass intake however is unclear, particularly during different seasons when grass availability and quality varies.

6.1.1 Study Aims

The following study was undertaken to determine the daily vDMI by donkeys managed with grass intake regulated by either strip grazing or by using a set stocking system. To enable the influence of pasture availability and quality on intake to be determined in the set stocking system the experiment was undertaken during two seasons, summer and autumn. Daily intake of pasture and barley straw was estimated from information on diet composition. The study aimed to:

1. Determine the affect of strip grazing and set stocking grazing systems on food intake by donkeys in Devon in summer and autumn

Research Objectives

- Using the *n*-alkane technique, estimate total daily DMI by donkeys managed using a strip grazing or set stocking grazing system
- Estimate the proportion of grass and supplementary barley straw in the diet of donkeys managed using each grazing system

6.2 MATERIALS AND METHODS

6.2.1 Experimental Design

The study took place at The Donkey Sanctuary, Sidmouth, Devon, UK. The study consisted of two experimental periods; Period 1 represented the start of the summer grazing season, when available pasture was abundant (summer, May 27th – June 10th 2005), Period 2 represented the end of the grazing season, when pasture was sparse (autumn, August 26th – September 9th 2005). To assess for the effect of set stocking and strip grazing on DMI simultaneously, two separate study sites were chosen. Site-1 was used to assess the effects of strip grazing and Site-2 for the effects of set stocking. Prior to the start of the study the donkeys on both study sites were accustomed to their surroundings and management routine. Each experimental period lasted 15 days. During the final 12 days of each experimental period, an *n*-alkane marker was administered and food and faecal samples taken.

6.2.2 Animals and Management

Twenty six mature donkeys, 13 for strip grazing and 13 for set stocking, were selected for the study. Ten donkeys (starting body weights 155 – 235kg strip grazing group, 157 – 248kg set stocking group) were selected for each study site during the summer experimental period. During the autumn experimental period all 13 donkeys on each study site were used (starting body weights 159 – 235kg strip grazing, 156 – 241kg set stocking). Donkeys in the strip grazing group were managed as part of a larger group of animals (38 donkeys, 1 horse and 1 mule). Donkeys in the set stocking group were managed as a separate group to all other donkeys at the sanctuary. The donkeys were weighed using a mobile weigh bridge in the morning of days 1, 8 and 15 of each experimental period. The donkeys were managed with 24 hour access to pasture every day during the study.

The strip grazing site was based on a hill with gradient 11% and total grazing area of approximately 0.74 ha (0.01 ha/animal) . Donkeys managed using set stocking were restricted to a flat area of pasture of approximately 0.2 ha for the duration of each experimental period (0.02 ha/donkey). Prior to the study the pasture at the set stocking site had been rested, resulting in a tall sward approximately 1 metre in height. The ample amount of pasture on offer at the study site was in contrast to the short pastures the study donkeys were accustomed to grazing, and therefore a potential risk factor for the donkeys suffering pasture associated laminitis. One week before the start of the first experimental period (summer) the pasture was topped, with the aim of preventing donkeys consuming excessive quantities of pasture and suffering associated health problems. At Site 1, strip grazing using an electric fence was used to regulate the amount of fresh, ungrazed pasture available to the donkeys. The length of the electric fence (135 meters) was moved approximately 0.3 meters per day, exposing fresh ungrazed pasture. All other areas of the grazing area had been continuously grazed by the group prior to the study, producing a uniform pasture of short length. Access to a yarded area with shelter, water and barley straw was available to all donkeys at both study sites at all times. Fresh straw was offered at 09:00h and 17:00h. The donkeys followed routine farriery, dental, vaccination and parasitic treatments throughout the study according to normal Donkey Sanctuary policy.

6.2.3 *N*-Alkane Marker

The same MW biscuits used in Chapter 5 were also used in this experiment to administer the *n*-alkane Dotriacontane (C_{32}) to the donkeys. The same procedures were followed for preparing the alkane/heptane solution and cooking of the biscuits as those described for Chapter 5. Each MW contained 6ml of alkane/heptane solution (75mg of C_{32}). The higher concentration of alkane in each biscuit in this study compared to that in Chapter 5 allowed administration of the marker to be reduced to twice daily, necessary due to time constraints of this study. For the last 12 days of the summer and autumn experimental periods each donkey received a MW at 07:00h and 17:00h. Straw, pasture and faecal samples were analysed for their *n*-alkane content as described in Chapter 5. Dry matter intake, diet composition and DEI were estimated as described in Chapter 5 (See 5.3.5., *N*-Alkane Analysis).

6.2.4 Sample Collection

Daily samples of barley straw offered and fresh ungrazed pasture were taken for the final 8 days of each experimental period for each study site. Straw samples were collected and pooled as for Chapter 5.

The pasture available to the donkeys at both sites was sampled daily using a 30 by 30cm quadrat. At site 1 (strip grazing) the quadrat was thrown onto the fresh, ungrazed pasture that would be available to the donkeys that day at 10 random intervals along the fence line prior to moving the electric fence. Samples were taken at the same time each day (07:15h). For each quadrat the pasture was cut at approximately 2cm above soil level to mimic the close grazing of pasture by donkeys. Cuttings from each quadrat were placed into a clean bucket until all 10 samples were taken. Pasture cuttings were chopped and pooled as described in

Chapter 5. At site 2 (set stocking) pasture samples were taken of the areas of pasture being actively grazed by donkeys at the time of sampling (08:00h). For each donkey the quadrat was placed as close to the area of pasture being grazed and pasture cuttings taken as previously described. Cuttings from all donkeys were pooled to produce one pasture sample per day.

Procedures for drying pasture samples, and for collection, storage, pooling and drying of faecal samples were as those described in Chapter 5. At the end of each experimental period and for each study site, dried pasture samples were pooled, a subsample taken and retained for nutritional analysis.

6.2.5 Nutritional Analysis

Prior to analysis all dried samples (straw, pasture and faeces) were ground using a hammer mill through a 1mm screen.

Straw, pasture and faecal samples were analysed for rDM, GE, CP, NDF and ADF according to the methods reported by the Association of Official Analytic Chemists (1990). *In vitro* DMD was determined using the NCGD technique described by ANKOM technology (Ankom, 2006) (See 3.2.5, Food Sample Analysis).

6.2.6 Statistical Analysis

Data were checked for normality of distribution and similarity of variance between treatments using the Anderson-Darling and Levene tests, respectively. Where data were normal the mean and standard error are reported. Where data were not normal the median and interquartile ranges are reported.

Results for DMI on a daily basis were normal distributed, therefore any effect of season and grazing group was tested using analysis of covariance (ANCOVA) to account for differences in herbage mass between study sites and seasons. Daily

DEI's were also normally distributed therefore two-way ANOVA was used to test for any effect of season and grazing group. Differences between grazing group DM and DE intakes were identified using the Tukey test. Results for diet composition and DM and DE intakes on a metabolic body weight basis were not normal, therefore the Kruskal-Wallis test was used to assess for differences between grazing groups and differences between seasons. All statistical analysis was carried out using Minitab 15 (Minitab Ltd, Coventry, UK).

6.3 RESULTS

6.3.1 Food Offered

The nutrient content of the barley straw offered, and pasture available to donkeys at each study site during summer and autumn, are shown in Table 6.1. Barley straw from the same harvest was fed to all donkeys during both seasons, producing similar results for nutrient content. Compared to published values, the barley straw fed in this study had a very high NDF and ADF content, producing forage of poor digestibility, shown by the low *in vitro* DMD results.

Topping of the pasture prior to the study at the set stocking site prevented collection and identification of plant species. Grazing pasture at the strip grazing site was a mixture of grasses (*Lolium perenne*, *Festuca rubra*, *Cynosurus cristatus*, *Dactylis glomerata*), herbs (*Taraxacum officinale*, *Bellis perennis*, *Stellaria media*, *Plantago major*, *Rumex obtusifolius*, *Ranunculus acris*) and the legume white clover (*Trifolium repens*). During summer the pasture available to the donkeys in the strip grazing group was of better quality than the pasture available to donkeys in the set stocking group, with higher GE and CP, lower cell wall content, and higher *in vitro* DMD. Herbage mass during summer at the strip grazing site was higher (165 $\pm$ 5.5g DM/m^2) than that at the set stocking site (114 $\pm$ 16.6g DM/m^2), due to topping of the pasture at Site 2. During autumn herbage mass was higher at the set stocking site (96 $\pm$ 6.4g DM/m^2 vs. 58 $\pm$ 3.6g DM/m^2), although grazing pastures at both study sites were similar in nutrient content and *in vitro* DMD. Pasture at both the strip grazing and set stocking sites were of higher nutritional quality during autumn compared to summer.

Table 6.1. Nutritional composition of foods offered during each season (g/kg DM unless otherwise stated)

	Strip Grazing		**Set Stocking**	
	Pasture (*n*)	**Straw (*n*)**	**Pasture (*n*)**	**Straw (*n*)**
Period 1				
Summer (May – Jun)				
Herbage mass $\pm$ s.e. (g DM/m^2)	165 $\pm$ 5.5	-	114 $\pm$ 16.6	-
aHM (g DM/donkey/day)	126	-	1754	-
DM (g/kg)	165 (24)	866 (8)	114 (8)	894 (1)
GE (MJ/kg DM)	17.1 (3)	18.5 (1)	16.6 (1)	16.9 (1)
CP	104 (24)	28 (1)	89 (8)	34 (1)
NDF	596 (48)	924 (2)	716 (16)	902 (2)
ADF	329 (48)	640 (2)	384 (16)	604 (2)
† *In vitro* DMD	0.64 (48)	0.21 (2)	0.47 (16)	0.24 (2)
Period 2				
Autumn (Aug – Sep)				
Herbage mass $\pm$ s.e. (g DM/m^2)	58 $\pm$ 3.6	-	96 $\pm$ 6.4	-
aHM (g DM/donkey/day)	44	-	1477	-
DM (g/kg)	171 (24)	893 (1)	151 (8)	882 (1)
GE (MJ/kg DM)	17.5 (3)	16.8 (1)	17.9 (1)	16.8 (1)
CP	152 (9)	27 (1)	170 (3)	27 (1)
NDF	638 (9)	903 (2)	630 (3)	920 (2)
ADF	323 (9)	592 (2)	292 (3)	584 (2)
† *In vitro* DMD	0.67 (9)	0.20 (2)	0.70 (3)	0.26 (2)

aHM: Herbage mass available to each donkey per day
† *In vitro* dry matter digestibility determined via NCGD analysis (neutral cellulase plus gamanase)
n: Number of samples analysed

Table 6.2. Mean (± s.e.) daily dry matter intake (DMI), digestible energy intake (DEI) (pasture and straw combined) and dry matter digestibility (DMD) by donkeys managed using a strip grazing and set stocking grazing system during summer and autumn. Percentage of grass and straw consumed, and DM and DE intakes on a metabolic body weight basis, shown as median (interquartile range)

Grazing System	% of Total Intake		DMI						DEI				Diet Energy Density	
(*n*)	Grass	Straw	**kg/day**	s.e.	**g/kg $BW^{0.75}$**	Interquartile range	**DMD**	s.e.	**MJ/day**	s.e.	**MJ/kg $BW^{0.75}$**	Interquartile range	**MJ/kg DM**	s.e.
Period 1 Summer (May – Jun)														
Strip Grazing (10) HM: 165 ± 5.5g	8	92	2.84	0.159	55	49.2, 63.4	0.49	0.032	34.9	3.07	0.64	0.546, 0.825	12.1	0.41
Set Stocking (10) HM: 114 ± 16.6g	56	44	2.17	0.218	42	31.9, 48.3	0.39	0.026	19.3	2.44	0.39	0.240, 0.448	8.9	0.34
Significance of effect of grazing system	***	***	*		**		**		***		***		***	
Period 2 Autumn (Aug – Sep)														
Strip Grazing (13) HM: 58 ± 3.6g	0	100	2.36	0.175	44	41.4, 49.2	0.34	0.039	20.9	2.66	0.39	0.335, 0.471	8.5	0.56
Set Stocking (13) HM: 96 ± 6.4g	18	82	2.43	0.135	45	40.7, 53.0	0.44	0.028	23.4	1.79	0.43	0.380, 0.539	9.5	0.38
Significance of effect of grazing system	***	***	NS		NS		NS		NS		NS		NS	
Significance of effect of season	***	***	NS		NS		NS		NS		NS		*	

NS: Not significant, * $P<0.05$, ** $P<0.01$, *** $P<0.001$
HM: Herbage mass ± s.e. (g DM/m^2)
n: Number of animals per grazing system

6.3.2 Food Intake

Dry matter and DE intakes by donkeys in each grazing system are shown in Table 6.2. Herbage mass appeared to influence DMI in both seasons. During summer (herbage mass - strip grazing 165 ± 5.5g DM/m^2; set stocking 114 ± 16.6g DM/m^2), when herbage mass was higher at the strip grazing site, donkeys in the strip grazing group had significantly higher intakes on a daily ($P<0.05$) and metabolic body weight ($P<0.01$) basis than donkeys managed using set stocking. During autumn (herbage mass - strip grazing 58 ± 3.6g DM/m^2; set stocking 96 ± 6.4g DM/m^2), DMI between management systems were statistically similar, although the greater herbage mass of the set stocking site increased DMI by donkeys in the set stocking group compared to intakes recorded in summer. In contrast, DMI recorded for donkeys in the strip grazing group were lower in autumn, coinciding with a considerably lower herbage mass at this site compared to that in summer. The amount of food consumed did not differ significantly between seasons.

Apparent DMD of the diets consumed by donkeys did not differ between seasons or grazing systems in autumn, although there was a significant effect of grazing system in summer ($P<0.01$). Apparent digestibility of the ration consumed by the set stocking group was considerably lower due to the much higher fibre content of the summer pasture at the set stocking site, despite donkeys in the set stocking group eating less straw ($P<0.001$) than those in the strip grazing group (Figure 6.1). The poor quality of the diet consumed by the set stocking group, combined with the lower food intake, resulted in significantly lower DEI (MJ/day and on a metabolic body weight basis) and ration energy density, compared to the strip grazing group ($P<0.001$). In contrast, the pastures on both study sites were of similar nutritional value in autumn (Table 6.1) leading to statistically similar DMD and DEI results for both grazing systems.

6.3.3 Diet Composition

Composition of diets selected by donkeys was affected by grazing system and season (Figures 6.1 and 6.2). An initial review of total daily DMI indicated an effect of herbage mass on food intake, where donkeys managed on the sites with the greatest herbage mass (strip grazing – summer, set stocking – autumn) ate the most food. However, analysis of the diet composition showed the higher DMI were due to higher straw intakes and not higher pasture intake. During summer, donkeys in the strip grazing group consumed significantly less grass and more straw ($P<0.001$) than those in the set stocking group, despite the greater herbage mass at the strip grazing site. This result probably reflects the further distance and greater incline the donkeys in the strip grazing group had to travel to reach fresh pasture. In autumn, the donkeys in the strip grazing system consumed almost no pasture (0 – 264g DM/day) compared to those in the set stocking group (284 – 678g DM/day). This low intake of pasture by the strip grazing donkeys supports the view that pasture availability affects pasture intake, but also suggests that foraging effort influences the donkey's response to pasture availability.

Figure 6.1. Median proportions of grass and straw comprising the diets of donkeys managed using a strip grazing and set stocking grazing system during summer and autumn
Numbers in parenthesis represent number of donkeys each period

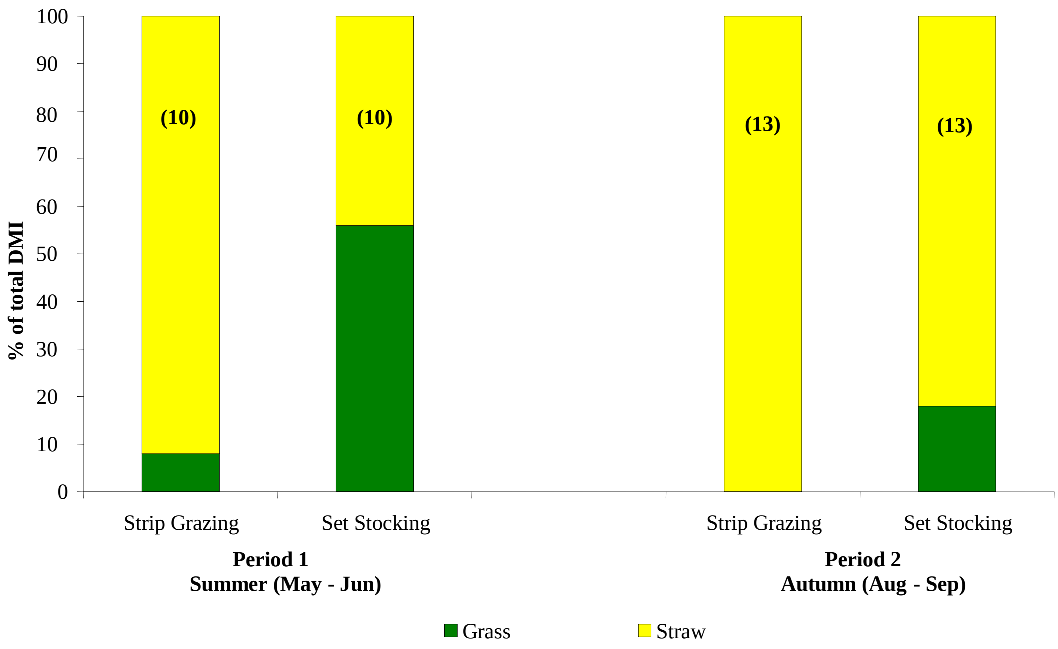
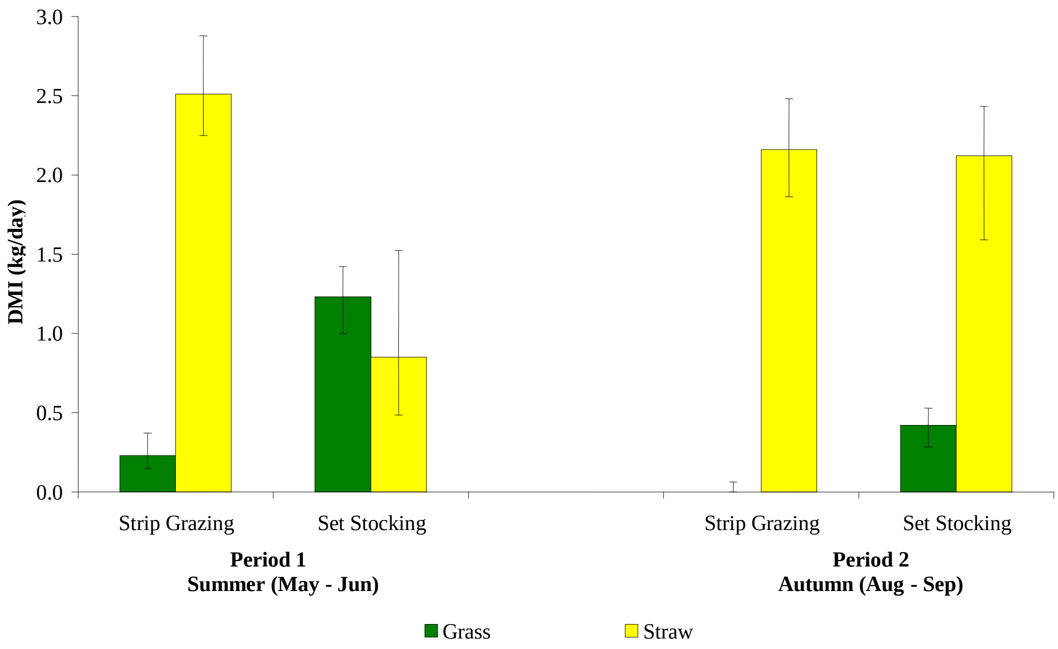


Figure 6.2. Median (interquartile range) daily dry matter intake (DMI) of grass and straw by donkeys managed using a strip grazing and set stocking grazing system during summer and autumn
Same number of donkeys used as Figure 6.1



6.4 DISCUSSION

6.4.1 Food Offered

The basis of testing the effects of set stocking were that the amount of pasture available per donkey would change, to assess if less pasture reduced grass intake and more pasture increased intake. Changing pasture availability per donkey could be achieved by either varying donkey stocking density or changes in pasture availability and quality. Experimental constraints prevented variation in stocking density, therefore seasonal variation in pasture availability and quality was used to assess for the effects of set stocking on food intake and diet composition. Differences in pasture quality between seasons were achieved at the set stocking site, with the pasture available during summer being of lower quality than that available during autumn. As expected, the lower quality pasture during summer coincided with greater herbage mass. Comparison of pasture quality with published values (McDonald *et al*., 2002) shows that the pasture available at the set stocking site during summer was at a late growth stage due to the high fibre and low CP content. This poor quality pasture, combined with the low quality straw, produced the lowest quality diet of the study. In contrast, the pasture at the strip grazing site during summer comprised of younger material, increasing the quality of the diet available to donkeys managed using this grazing system. Differences in pasture quality between study sites were negligible during autumn.

6.4.2 Food Intake

Total food intakes by the donkeys in this study are similar to those reported for grazing donkeys in Chapter 5 and for housed donkeys (Chapter 4). The similarities in intakes between these studies when using different groups of donkeys indicate that the results are representative of voluntary food intake by mature donkeys. Similarity in results also indicate that findings from these studies are likely to be applicable to the wider UK donkey population with access to sparse pastures, although further research into the affects of regional differences in climate, food availability and food quality is required to confirm this conclusion.

The results from this study also support the view that donkeys in the UK have lower food intakes than have been previously reported. The similarity in DMI between the two grazing studies reported in this thesis suggests that when grazing, donkeys regulate their food intake, with energy requirements seeming to be the regulating factor. Mean body weight changes per donkey of less than 5kg were recorded for donkeys in each grazing group during each season (summer; -0.05kg strip grazing, -2.65kg set stocking, autumn; -4.92kg strip grazing, -2.77kg set stocking), indicating the donkeys were satisfying maintenance energy requirements. Digestible energy intakes on a metabolic body weight basis in this study were higher than calculated maintenance requirements for housed donkeys during summer and autumn but similar to DEI reported for grazing donkeys in Chapter 5. The exception to this finding was the significantly higher DEI by the donkeys managed using the strip grazing system during summer. Calculated energy intakes by these donkeys were double maintenance requirements, and almost twice those of the donkeys in the set stocking group during the same recording period. One explanation for the higher energy intakes by the strip grazing group may be a greater energy requirement for grazing and daily activity, although daily behaviour activities were not recorded in this study.

The grazing area available to the donkeys at the strip grazing site was larger than that available at the set stocking site and required the donkeys to walk up hill to access fresh pasture. Donkeys walking up hill require considerably more energy than walking on level ground (Yousef, Dill & Freeland, 1972), hence the donkeys in the strip grazing group would have expended more energy whilst searching for food. Results from diet composition support the theory that the higher energy intakes were due to increased activity requirements. In autumn, when herbage mass was considerably lower, the donkeys in the strip grazing group consumed little or no pasture and maintained body weight on lower energy intakes. Thus, it is surmised that the donkeys in the strip grazing group spent more time grazing during summer compared to autumn, increasing energy requirements.

Effect of Season and Grazing System

The lack of any significant affect of season on daily DM and DE intakes provides further evidence that donkeys account for changes in pasture availability and quality to regulate their food intake to meet energy requirements. Food availability is the primary factor influencing food intake, however, results show an interaction between pasture availability and quality. When pasture was more abundant the donkeys increased their total daily food intake, reflected by the higher DMI by the strip grazing group during summer and the set stocking group during autumn. However, the lower DMI by the set stocking group in summer compared to during autumn shows that although there was more grass available to graze during summer, the poor quality of the pasture reduced food intake. This difference in pasture quality between the strip grazing and set stocking sites was the cause of the slight significant difference recorded between the DMI of the two grazing systems during summer.

During autumn, when pasture quality was the same on both study sites, daily DMI by donkeys in both groups were statistically similar. The lack of any effect of grazing system on daily food intake indicates that neither system is better at managing food intake, although these results would have been influenced by the *ad libitum* access the donkeys had to straw. Results from diet composition show differences in grass intake between grazing groups, however, it is proposed that differences in grazing area, pasture quality and herbage mass were of greater influence than grazing system on grass intake.

6.4.3 Diet Composition

Results on diet composition from Chapter 5 lead to the view that it is necessary for donkeys to consume a certain quantity of fibre per day. Calculation of NDF intakes by the donkeys in the present study support this view, with average seasonal NDF intakes being almost identical to those by the donkeys in Chapter 5 (present study; summer 2.14kg, autumn 2.12kg, Chapter 5; summer 2.07kg, autumn 2.11kg). Only during summer did mean daily NDF intakes differ significantly between grazing groups, with donkeys in the strip grazing group having higher intakes due to the higher straw content of their diet (strip grazing; 1.82 – 3.59kg NDF, mean 2.54kg, set stocking; 0.93 – 2.59kg NDF, mean 1.73kg, $P<0.01$). At present there are no scientifically validated recommendations for minimum fibre content in the equine diet. Current recommendations for horses state feeding fibre in the form of either long-stem forage or pasture at a minimum level of 1% body weight per day (NRC, 2007). Daily NDF intakes by the donkeys in the present study varied from 0.6% to 2.1% body weight, although the average NDF intake (1.1% BW) indicates the current recommendation for minimum fibre requirement in the equine diet is reasonable for mature donkeys.

The corresponding increase in total daily food intake as herbage mass increased indicated that the donkeys responded to greater pasture availability by eating more grass. During autumn this response was observed, with donkeys in the set stocking group consuming significantly more grass than those managed using strip grazing. During summer, however, the donkeys in the strip grazing group, where pasture was of greater herbage mass (g DM/m^2), ate significantly less grass than donkeys managed using set stocking. The lower grass intakes by the strip grazing group were probably due to the lower pasture availability per donkey at the strip grazing sight compared to the set stocking site (Table 6.3). Although herbage mass in the remainder of the strip grazing field was not measured, it was observed that the donkeys grazed the pasture to just above soil level, reducing herbage mass in the remainder of the field to very low levels. The lower grass intakes by the strip grazing group were therefore probably due to reduced pasture availability. The further distance the strip grazing group had to travel to reach fresh pasture would also have increased foraging effort.

Table 6.3. Estimated herbage mass (g DM/donkey/day) available to donkeys during summer and autumn managed using the strip grazing and set stocking systems

	Herbage Mass Available (g DM/donkey)	
Grazing System	**Period 1** Summer (May – Jun)	**Period 2** Autumn (Aug – Sep)
Strip Grazing	126	44
Set Stocking	1754	1477

The combination of the considerably lower pasture availability per donkey at the strip grazing site during autumn, and the higher foraging effort of these donkeys compared to those at the set stocking site, provides an explanation for the median grass intake of this group being calculated as zero during autumn (Figure 6.2). However, during routine collection of pasture and faecal samples donkeys in the strip grazing group were observed grazing during both seasons.

Error in diet composition analysis using the EatWhat software package has been previously reported in a study of grazing sheep (Lee & MacGregor, 2004). Error in estimating diet composition from alkanes can be due to a number of factors (Dove & Mayes, 1991; Dove & Moore, 1995). When grazing pastures contain many different plant species, or when trying to identify different plant parts within the diet, the presence of more species than alkanes requires plants to be grouped, according to similar properties, in order for individual alkane profiles to be identified. Grouping plants can lead to vital data being removed and error in the estimate of diet composition. In addition, plant species with similar alkane profiles can make identifying individual plant species difficult. In the present study only two dietary components were identified, straw and grass, hence there should have been no difficulty in separating their alkane profiles. During autumn, however, the alkane profiles of straw and grass samples from both study sites were more similar than during summer (Table 6.4). Analysis of the 'best solutions' results from the EatWhat software, however, showed there was sufficient difference in the alkane concentrations of the two dietary components for grass to be distinguished from straw (Dove & Moore, 1995). Further errors can occur in the alkane analysis of faecal and dietary samples, although if this was the case in the present study errors would have occurred during the analysis of samples from both study sites, and both seasons, as all samples were analysed at the same time. The most likely error to have influenced diet composition results for the strip grazing group during autumn is collection of non representative pasture samples. Although the donkeys were observed predominantly grazing the fresh pasture available upon moving the fence, the shortness of the grass in the remainder of the field clearly indicated the donkeys were also grazing this area. Pasture in the remainder of the field was too short to collect, thus any grass consumed from this area of the field was not accounted for in the sampling process, and may therefore not be identified in estimation of the diet composition. Despite these possible errors in estimating diet composition, it remains the view of the author that the primary explanation for the low grass intake by the donkeys in the strip grazing group in autumn was the additional foraging effort experienced by these donkeys and the low availability of grass on offer.

Table 6.4. Alkane (mg/kg DM) profiles of grass and straw samples from the strip grazing and set stocking study sites during summer and autumn

System	Dietary Component	Alkane (mg/kg DM)				
		C25	C27	C29	C31	C33
Period 1 Summer (May – Jun)						
Strip Grazing	Grass	13.43	26.54	120.28	193.47	35.66
	Straw	3.18	4.77	16.79	19.92	6.23
Set Stocking	Grass	5.47	9.06	40.95	73.80	32.73
	Straw	3.27	5.39	23.52	42.29	12.71
Period 2 Autumn (Aug – Sep)						
Strip Grazing	Grass	8.31	15.72	50.23	84.95	55.17
	Straw	6.93	9.07	36.03	62.20	21.65
Set Stocking	Grass	8.63	13.82	34.31	58.73	46.59
	Straw	5.53	7.60	31.55	52.68	17.05

6.5 CONCLUSIONS

The aim of this study was to assess the influence of a strip grazing and a set stocking system on grass intake by donkeys. Although donkeys were observed grazing during both seasons, and in both grazing systems, the low herbage mass of the pasture at the strip grazing site limited the amount of grass donkeys could consume. The extreme restriction on the amount of grass the strip grazing group could consume prevented accurate estimation of diet composition by donkeys managed using this system. In addition, accurately determining if either grazing system was more effective at regulating grass intake was impossible due to the differences in pasture availability between study sites.

What was determined from this study was that donkeys are able to compensate for changing pasture availability if additional forages are provided. Results also indicate that donkeys have a requirement for a certain level of fibre in their diet. If this is the case, grazing pastures in the UK are unlikely to provide adequate fibre intakes, necessitating the feeding of high fibre forages in addition to grazing.

Dry matter intakes by donkeys managed using the strip grazing and set stocking systems ranged from 42 to 55g/kg $BW^{0.75}$, similar to those by grazing donkeys reported in Chapter 5 (45 – 58g/kg $BW^{0.75}$). The primary regulator of intake in this study and that reported in Chapter 5, appears to be energy requirements. The regulation of intake to meet energy demands by grazing donkeys is an encouraging result for donkey owners aiming to maintain their donkeys at a healthy body weight. Food intake, however, was influenced by the low herbage mass of the available pasture. Further investigation is needed to determine if donkeys continue to regulate their food intake to satisfy energy requirements when pasture is more abundant, as is likely the case in many individual donkey homes. Result from this study lead to the conclusion that when pasture availability is low, neither strip grazing nor set stocking promotes or regulates grass intake, with herbage mass having a greater influence over grass intake.

6.5.1 Future Work

Further investigation is needed to assess the effects of a set stocking and a strip grazing system on intake by grazing donkeys. Future studies should aim to provide adequate herbage mass to prevent grass intake being restricted by availability of pasture. Herbage mass per donkey should be similar for both grazing systems to enable comparison between systems, and advantages or disadvantages of each grazing system for managing intake to be identified.

A second area requiring further investigation is the necessity for a certain level of fibre in the diet of donkeys. Establishing the minimum requirement for dietary fibre will enable more accurate selection of suitable food sources to be included in the diets of donkeys.

CHAPTER 7
GENERAL DISCUSSION

7.1 SUMMARY

Anecdotal evidence from UK equine charities indicates that obesity is common amongst the UK donkey population. The lack of feeding advice and guidelines available to owners on how to feed donkeys likely contributes to the problem. It was proposed that due to this lack of information owners find it difficult to know what diets and rations to feed their donkeys, leading to donkeys suffering malnutrition or obesity. The high incidence of obesity in UK donkeys, combined with previous research showing donkeys have superior digestive efficiency compared to horses, suggest that donkeys require less DE to maintain body weight than horses. Differences in DE requirements between donkeys and horses would make the use of feeding advice and guidelines formulated for horses unsuitable for donkeys, requiring donkey specific feeding guidelines to be compiled. The main objectives of this thesis were to gather information on donkey body condition score, energy requirements, feeding and grazing behaviour and the husbandry and feeding practices used to manage UK donkeys, with the aim of formulating practical feeding guidelines for donkeys.

Results from the donkey survey showed that in the UK the majority of donkeys surveyed were in ideal body condition (Chapter 3, Figure 3.5). However, overweight donkeys were common in the sample population, with an average of 24% being overweight, with the increasing probability of suffering health problems associated with excess weight. Donkeys carrying excess weight are more susceptible to becoming obese than those of ideal weight, therefore it is imperative that the reasons for any excesses in body weight be identified, leading to the question, why do donkeys gain weight?

7.2 RATIONS AND DIETS FED TO DONKEYS IN THE UK

It was proposed that many owners of donkeys did not know how much, or what types of foods their donkeys required. Results on feeding practices from the donkey survey support this theory, with 57 different foods being fed. The majority of owners fed forage based diets with straw, followed by hay, comprising the bulk of this food group. Forage diets, however, were frequently supplemented with higher energy concentrate feeds and chaffs. The feeding of concentrates to non-working donkeys in the UK is unnecessary. This is evident from the maintenance of donkeys during all seasons, on a diet of barley straw and grass hay, reported in Chapter 4.

A lack of seasonal variation in the types and amounts of foods fed also suggests that owners were uncertain about their donkey's nutritional requirements. The feeding of concentrates did decrease in spring and summer, indicating awareness by owners of either lower energy requirements, increased grass growth leading to an increased grass intake, or the ability of a forage only diet to provide adequate energy. Contrary to this finding was the lack of variation in the amount of forage fed during spring, summer and autumn, despite seasonal variation in pasture availability and quality, and grazing area and time. The feeding of multiple food types, and similar rations throughout the year, suggests that owners are unsure of their donkey's nutritional requirements and how to satisfy these requirements. Owners may also be uncertain of how to supplement pasture intake to ensure optimum vitamin and mineral balance within their donkey. Many of the chaffs and concentrate feeds fed during the survey contained vitamin and mineral compounds within their ingredients, with some feeds being promoted specifically as a way of providing vitamins and minerals to grass kept equines. The lack of information on vitamin and mineral requirements of donkeys, and if they differ from those of horses, makes it difficult to assess if supplementation is necessary. Free access to a vitamin and mineral block is likely to remove the need to feed specifically with the aim of balancing these nutrients.

The finding that owners adjusted grazing area and grazing time in response to changes in pasture availability indicates owners were aware of the potential intake of grass by their donkeys. From the grazing studies reported in Chapter 5 it is evident that the practice of increasing grazing times in spring and summer, reported by donkey owners, would lead to higher grass intakes (Chapter 5, Figure 5.4).

The practice of strip grazing in spring and summer would help to regulate access to fresh pasture, although the efficiency of strip grazing in reducing grass intake remains unclear. Reducing the grazing area available to donkeys was also common practice in spring and summer, and would likely have reduced grass intake due to a lower herbage mass available per donkey. Continued feeding of the same types and quantities of food from spring to autumn contrasts with the effort owners put into regulating the amount of grazing their donkeys have access to. The finding that owners predominantly adjusted their donkey's access to pasture, and not the amount of supplementary food offered, further supports the theory that owners require more information on their donkey's nutritional requirements, diets and rations most suitable for meeting these nutritional demands, and how to supplement pasture intake. From the grazing studies reported in Chapters 5 and 6, it is evident that donkeys are able to maintain body weight whilst at grass in spring, summer and autumn with straw as the only supplementary food. Owners could reduce feeding costs, and management demands, by reduced feeding of supplementary foods, whilst allowing their donkey longer grazing times or larger grazing areas, thus utilising the nutritional content of the pasture their donkey is already grazing.

Prevention of weight gain therefore requires owners to select suitable diets and feed appropriate quantities, allowing donkeys to satisfy their DMI requirements without consuming excess energy. Reducing grazing area, grazing time, or pasture herbage mass, would help to reduce grass intake, however, it would probably be more economical, and practical, for owners to adjust the amount and types of supplementary feeds fed. Results from the survey did show that owners adjusted the amount of concentrate feeds fed to their donkeys during different seasons. However, there remained a reliance on supplementary foods to satisfy donkey nutritional requirements, despite a natural food source being available to their donkey whilst grazing. The provision of supplementary foods to donkeys with access to pasture is particularly unnecessary as pastures grazed by donkeys in the UK usually have higher nutritional value than the sparse, low quality grazing donkeys are evolutionarily adapted to survive from. It is concluded that although owners showed an awareness of their donkey's dietary needs, the practice of feeding unnecessary concentrates, chaffs and high energy forages, in addition to grazing, results in donkeys being overfed, supporting the proposal that donkey specific feeding guidelines are required to help prevent donkeys becoming overweight.

7.3 SUITABILITY OF HORSE FEEDING RECOMMENDATIONS FOR DONKEYS

The study of donkey energy requirements reported in Chapter 4 confirms that mature donkeys have lower maintenance DE requirements than horses (Chapter 4, Figure 4.9). Digestible energy requirements of donkeys during spring, summer and autumn averaged 0.32MJ/kg $BW^{0.75}$, 55% of DE requirements of horses and ponies according to NRC (2007) calculations. Corresponding results for donkeys in winter were 0.43MJ DE/kg $BW^{0.75}$, 77% of horse feeding recommendations. Dry matter intakes by the donkeys studied (12 – 18g/kg BW) were also lower than is recommended for horses (15 – 25g/kg BW), making donkeys more susceptible to weight gain if fed rations similar to those fed to horses.

Results from the DE and grazing studies show that mature donkeys are able to maintain body weight on a diet of straw and hay when stabled, or just straw when allowed access to grazing pasture. Donkeys do not require high energy concentrate and alfalfa based chaffs. The inclusion of these high energy feeds in the diets of many UK donkeys indicates that advice on foods most suitable for feeding to donkeys is required.

Sources of advice for donkey owners on how to feed their donkeys are more limited than those for horse owners. Scientifically validated feeding recommendations for horses enable equine nutritionists to estimate the nutritional requirements of horses and ponies with a certain degree of accuracy. Such calculations allow equine feed manufacturers, independent nutritionists and vets, to advise owners on the most suitable diets and rations for their animals, providing multiple points of reference for horse owners. The lack of scientifically validated feeding guidelines for donkeys makes calculating donkey nutritional requirements difficult. As a result, advice on feeding donkeys is more limited. The only feeding recommendations for donkeys at present are those provided by Taylor (2000), estimated from horse feeding guidelines. Comparison of these recommendations with directly measured DE requirements of donkeys measured in the trial reported here show that Taylor (2000) overestimated the DE requirements of donkeys. During spring, summer and autumn, DE requirements of donkeys were 73% of DE requirements calculated according to Taylor (2000). Only in winter were current feeding recommendations for donkeys accurate. It is therefore concluded that neither horse, nor current donkey, feeding recommendations calculate donkey DE requirements accurately during spring, summer and autumn, requiring donkey specific feeding guidelines to be compiled.

The formulation of donkey specific feeding guidelines will provide owners with a standard from which they can estimate their donkey's dietary requirements. Donkey feeding guidelines will also enable equine nutritionists and vets, to advise owners how to feed their donkey correctly, providing a further point of contact and support for donkey owners.

7.4 EFFECT OF MANAGEMENT PRACTICES ON DRY MATTER INTAKE BY GRAZING DONKEYS

Results from Chapters 5 and 6 provide the first information on how grazing donkeys in the UK adapt their feeding strategy to changes in their environment. Previous research shows that the donkey has retained a feeding strategy that is advantageous in areas of poor food quality, and low availability. The combination of lower food intakes, and greater digestive efficiency, compared to horses and ponies (Cuddeford *et al*., 1995; Pearson *et al*., 2001), places the donkey at an advantage when faced with food shortages. The finding that donkeys have lower DE requirements than horses (Chapter 4) is an additional advantage when food resources are limited. In the UK, where the diets of donkeys usually consist of temperate grazing pastures, combined with preserved forages and concentrate foods, the feeding strategy of the donkey may not be so advantageous, and could easily lead to excess energy intakes and weight gain if food intake is not managed.

Results from Chapters 5 and 6 indicate that DMI by donkeys with access to temperate pastures, and supplementary forage, range from 42 to 58g/kg $BW^{0.75}$. The primary regulator of intake in these experiments appeared to be energy requirements, although consumption of similar quantities of fibre also suggests donkeys have a requirement for a certain level of fibre in their diet. The regulation of intake to meet energy demands by grazing donkeys is an encouraging result for owners aiming to maintain their donkeys at a healthy body weight. Food intake during both experiments, however, would have been influenced by the low herbage mass of the available pasture (summer 114 $\pm$ 17g to 197 $\pm$ 12g DM/m^2, autumn 58 $\pm$ 4g to 96 $\pm$ 6g DM/m^2). Whether donkeys continue to regulate their food intake to satisfy energy requirements when pasture is more abundant continues to require further investigation. In spite of this limitation, the results show that donkeys do not require high quality pastures in abundance, but that they can be kept on pastures with little available grazing if supplementary forage is provided. The provision of a fibrous forage such as straw enables the donkey to satisfy its appetite and dietary requirement for fibre that would otherwise require large volumes of grass to be consumed, increasing energy intake and the susceptibility to pasture induced laminitis.

7.4.1 Effect of Grazing Time

During autumn, restricting grazing time did not affect the donkeys grass intake, or the time spent grazing, thus herbage mass, and not grazing access time, was the influencing factor on grass intake during autumn. When pasture is of low availability, the results reported here indicate that there is little benefit in restricting grazing time when trying to reduce grass intake. However, this result must be applied with caution to the wider UK donkey population as the very low herbage mass recorded in this study may not be representative of grazing pastures available to donkeys in the rest of the UK.

During summer, grazing time did influence grass intake and grazing behaviour. When exposed to more abundant pastures, restricting the donkeys to 12 hours or less grazing per day, did reduce grass intake, despite the compensatory increase in grazing intensity. Another compensatory effect of shorter grazing times during both seasons appears to be greater diet digestibility. During autumn this greater digestive efficiency most likely resulted from a combination of a better quality diet and slower rate of passage of donkeys with 8 and 12 hours access compared to those with 23 hours access. During summer it appears that the greater DMD by the 8 and 12 hour groups was due to a longer retention time of food as the quality of the diet eaten by the 23 hour group would have been greater. It is therefore concluded that pasture availability (herbage mass) is more influential over pasture intake than grazing time. In situations where grazing is restricted, but there is free access to forage, donkeys are able to compensate for pasture restriction if an alternative forage is provided.

7.4.2 Effect of Grazing System

The influence of the strip grazing and set stocking systems on pasture intake by donkeys is difficult to determine from the results reported in Chapter 6 due to the considerable differences in the amount of pasture available per donkey. Analysis of covariance showed there was an effect of herbage mass on DMI (kg/day) each season, however *ad libitum* access to straw enabled the donkeys to compensate for differences in herbage mass, resulting in statistically similar DMI's each season.

The considerably lower herbage mass available to donkeys in the strip grazing group would have made it impossible for donkeys to consume equivalent grass intakes as those in the set stocking group. Results, however, do show how donkeys are able to compensate for changing pasture availability if additional food sources are provided. When the availability of pasture was low, as it was for the strip grazing group during both seasons, and for the set stocking group during autumn, the donkeys responded by consuming more straw. The substitution of grass by straw in the diet reflects the low DM intake from grass and possible feelings of hunger by the donkeys. An increased straw intake with reduced grass intake also indicates the donkeys were able, in some way, to assess the likely energy intake gained from continued grazing. Digestible energy intake results from the strip grazing group suggest that during summer, when pasture availability was higher, the donkeys expended more energy during daily activities compared to during autumn. The corresponding higher grass intakes during summer indicate this higher activity level was due to longer, or more intensive, grazing periods. Thus, it is proposed that during autumn when pasture availability at the strip grazing site was even lower, the donkeys reduced the energy expended whilst grazing by reducing grazing activity, leading to the significantly lower grass intakes during autumn. This response to low pasture availability was also exhibited by donkeys in Chapter 5 during autumn. Restricting donkeys to either 8, 12 or 23 hours daily grazing access did not affect grass intake (kg DM/day) or grazing time (hours/day), probably due to the low pasture availability per donkey (138g DM/donkey/day). Had the donkeys with 23 hours access grazed for longer, energy expended during this additional activity is likely to have been greater than would have been gained from any additional grass consumed. These combined results suggest that if pasture availability falls below a certain level, donkeys will substitute grass with straw. Results from the groups of donkeys managed using strip grazing indicate fresh pasture with a herbage mass of 140g DM or less per donkey per day, is low enough to reduce grass intake and promote straw intake. In contrast, herbage mass of 1477g DM per donkey per day reduced grass, and increased straw intake, by the donkeys in the set stocking group. Differences in results can be accounted for by differences in the area being measured, as the strip grazing value only represents the amount of pasture needed in the single strip of fresh pasture, with no account of the pasture available in the remainder of the field.

The ability to influence diet composition and reduce a donkey's grass intake without having to restrict grazing time is advantageous for both owner and donkey. Grazing donkeys on sparse pastures, with access to low energy forage, will enable donkeys to spend more time at pasture, reducing the amount of labour involved in keeping donkeys housed and enabling the donkey to exhibit its natural feeding behaviour.

7.5 FUTURE WORK

Maintenance DE requirements of mature donkeys in the UK receiving a forage only diet have been determined. The lower DE requirements of donkeys compared to horses confirm the unsuitability of horse feeding recommendations for calculating donkey requirements, and the necessity for donkey specific feeding recommendations. From the results reported in this thesis, recommendations for feeding donkeys are limited to DM and DE requirements of mature healthy donkeys for maintenance of body weight. Further research into the nutritional requirements of donkeys must focus on expanding our knowledge to match that of horse, livestock and companion animal nutrition, if feeding recommendations are to be of practical use to all donkey owners, both in the UK and in other countries. In the long term, future research should aim to calculate additional energy requirements of donkeys during periods of growth, pregnancy, lactation and when working. Calculation of DCP, vitamin and mineral requirements of donkeys should also be a long term aim. The focus of more immediate research should be expansion of the findings of this thesis, confirming results and assessing the influence of dietary factors on energy utilisation by donkeys. The focus of such research should be as follows;

- Measurement of energy losses and energy retention by donkeys when fed different diets to determine the NE gained from different food types and the effect of diet on DE requirements of donkeys. This would also allow the accuracy of the DE system for estimating energy requirements of donkeys to be assessed.
- Direct comparison of the energy losses from donkeys, horses and ponies measured using indirect calorimetry methods. This would allow relevant literature on horses to be transferred to donkeys with greater accuracy.

From the survey and grazing studies undertaken in this thesis it is evident that further investigation is needed to determine the affects of different management practices, in particular grazing systems, on pasture intake. Daily grass and DM intakes by donkeys with access to pasture were calculated successfully, however, results may not be applicable to the wider donkey population of the UK due to the low herbage mass of grazing pasture available to the donkeys in these studies. Although these results provide information on the response by donkeys to changing pasture availability and different grazing systems, further investigations are needed to determine if donkeys respond in the same way when pasture availability does not restrict grass intake. A better understanding of how these factors affect total food intake, and donkey body weight, will enable advice given to owners to be practical, and effective, in preventing donkeys becoming overweight. The focus of such research should be as follows;

- Accurate calculation of the quantities of conserved foods (concentrates, chaffs and forages) consumed by donkeys in private and foster homes, and a survey of why owners select to feed particular types and brands of food.
- Determination of the availability of grazing pasture to donkeys in the UK, through accurate assessment of the nutritional content, herbage mass and area of grazing pastures.
- Assessment of the affect of pasture quality, herbage mass, plant species and grazing area, on feeding behaviour, grass intake and total food intake by donkeys, with particular focus on the feeding behaviour and intake of donkeys when grazing more abundant pastures, and when no supplementary forage is provided .
- The effectiveness of different grazing systems on intake and feeding behaviour by donkeys when grass intake is not limited by pasture availability, as this was not achieved in the second grazing study due to exceedingly low herbage mass at the strip grazing site.

7.6 CONCLUSIONS

The ultimate aim of this thesis was to provide practical feeding guidelines for donkeys in the UK. Measured DM and DE intakes by mature donkeys during each UK season enabled recommendations for the maintenance DM and DE requirements of donkeys ranging in mature body weight from 100 to 250kg to be estimated (Chapter 8). From these estimates it is confirmed that donkeys require less DE than horses and that horse feeding recommendations, at least for energy, should not be used for calculating donkey requirements.

The survey of donkey husbandry practices indicated that approximately a quarter of donkeys in private and Donkey Sanctuary foster homes are overweight, although this figure may be an underestimation. The primary cause of excess weight in donkeys appears to be due to donkeys consuming too much food in total and not the overfeeding of high energy, cereal based concentrate feeds, or forages. Owners relied on the feeding of preserved foods during all seasons to provide their donkey's nutrition, and appeared to place little nutritional importance on pasture. The lack of information on grass intake and feeding behaviour of donkeys whilst grazing is the likely cause of this feeding practice. In view of these findings it is clear that donkey owners need to be educated in the nutritional value of all food types, including pasture. In order to make advice applicable to as many owners as possible, the feeding value of different forages, and the intake of grass by donkeys whilst grazing, must be determined under a variety of commonly used grazing systems. Herbage mass available was the most influential factor on grass intake by donkeys in the grazing studies, hence restricting grazing time was only effective in reducing grass intake when donkeys were grazing more abundant pastures in summer. In private homes donkeys may only graze pastures of low availability in winter, hence restricting grazing time would be a useful method for reducing grass intake in spring, summer and autumn by privately owned donkeys. However, it would be more practical to remove concentrates feeds from the diet and reduce the amount of chaffs and forages fed during these seasons, and offer a low energy forage such as straw, plus a vitamin and mineral block, allowing donkeys to graze for longer. Reducing grazing area, or strip grazing, may also reduce grass intake without having to limit grazing time, although further research is required to determine the affect of set stocking and strip grazing on grass intake by donkeys.

CHAPTER 8
PRACTICAL APPLICATION: DONKEY SPECIFIC FEEDING GUIDELINES

8.1 INTRODUCTION

Formulating a donkey's ration and deciding on what foods to offer requires knowledge of both the donkey's requirements, and the nutrient value of the foods available. When calculating energy requirements it is also imperative that the aim of the ration be determined, whether it be for the donkey to gain, maintain or lose body weight. The donkey's natural feeding behaviour must also be taken into account to ensure digestive health and reduce behavioural stress. Factors influencing donkey energy and nutrient requirements will affect individual donkeys in different ways. It is therefore essential that individual donkey rations are formulated based on assessment of each donkey's requirements.

8.2 ASSESSMENT OF DONKEY ENERGY REQUIREMENTS

Factors affecting the energy requirements of animals have been discussed in greater detail in Chapter 2. Below is an overview of the main factors that should be assessed before calculating a donkey's energy requirements.

The calculation of a donkey's energy requirements begins with an assessment of the donkey's body condition. The body condition score chart show in Figure 3.2, Chapter 3, was formulated for assessment of body condition in UK donkeys (The Donkey Sanctuary, 2005). Using the body condition score chart in Figure 3.2, place the donkey in one of the three fat classes (thin, moderate, fat) by comparing the donkeys body shape to those shown on the condition score chart, and by manually feeling the areas of the body where fat deposits occur (neck, withers, ribs, belly, back, loins and hindquarters). After determining the fat class that best describes the donkey, body condition score can be more precisely determined by using the descriptions of the various body areas and by feeling for fat deposits (Smith & Wood, 2008).

After assessment of the donkeys current condition score, a judgement can be made on whether the donkey should maintain its current body condition or gain or lose condition. This step is vital in ensuring donkeys remain in good health as it enables owners to adjust rations accordingly.

Assessment must also be made of any exercise requirements the donkey may have. Results from the survey reported in Chapter 3 indicated that the majority of donkeys in the UK are non-working companion animals. These donkeys would not require any additional energy for work. Owners exercising their donkeys may need to increase the amount of energy their donkey receives if they aim to maintain or improve body condition, however, there have been relatively few studies into the energy requirements of working donkeys (Yousef & Dill, 1969; Yousef *et al*., 1972; Pearson *et al*., 1998; Guerouali, Bouayard & Taouli, 2003). Owners are advised to monitor their donkey's body condition and adjust the energy content of the ration to account for any changes.

Energy requirements will also be affected by weather conditions. Although the DE recommendations provided in this chapter account for an increase in energy demand in winter, the effects of exposure to cold temperatures, rain and wind were not measured. Donkeys exposed to winter conditions will have an increased energy requirement for thermoregulation. In the DE studies reported in Chapter 4, the higher energy demand in winter was satisfied by increasing the amount of hay within the ration. Increasing the hay increased the amount of fermentable fibre in the ration, raising the heat increment of the diet. The added heat produced through fermentation of the hay would have aided the donkeys in maintaining body temperature. The effects of winter weather conditions can also be reduced by the provision of water proof rugs and field shelters. Field shelters will also provide shade from the sun during the spring and summer.

Finally rations may require adjustment for donkey age and temperament. Older donkeys may require more energy dense rations due to loss of body condition. Poor dentition is a common problem in older donkeys (Sprayson, 2008), and may contribute to a loss of body condition. Thus older donkeys require adequate energy in a form of food they can eat (soaked feed, chopped forages). Younger donkeys require additional energy for growth, and are likely to have a more alert temperament (personal observation), increasing energy requirements compared to more docile, mature donkeys.

8.2.1 Calculation of Donkey Energy Requirements

After assessment and consideration of the factors highlighted above, the energy requirements of the donkey can be estimated. Firstly the donkey's body weight must be measured or estimated using equation 3.1 (Chapter 3, 3.2.5 Quantitative Measurements). Recommended DEI can then be calculated from equation 8.1. It must be remembered however that the recommendations were formulated from studies on mature, healthy donkeys, and that the calculated DE requirement must be adjusted to account for individual donkey variation in body condition score, work/exercise requirements, climate, season, age and donkey temperament.

Equation 8.1.

Recommended DEI for maintenance (MJ/day) =

$$\text{Spring to Autumn} \quad = \quad 0.32 \times BW^{0.75}$$

$$\text{Winter} \quad = \quad 0.43 \times BW^{0.75}$$

Daily DM required can then be calculated. Dry matter intakes by donkeys when stabled ranged from 1.3 – 1.8% body weight, and 1.3 – 1.6% body weight when grazing. Dry matter intake is therefore recommended at 1.5% body weight for donkeys (15g/kg BW). To provide adequate DM without providing excess energy, a diet of straw supplemented with measured amounts of higher energy, more digestible forage, is recommended. Oat straw is considered the most palatable straw for feeding to equines (Lewis, 1995). Feeding straw *ad libitum* will allow donkeys to satisfy their appetite after consuming the higher energy forage. The feeding of concentrate feeds are unnecessary in the diet of mature healthy donkeys.

The required energy density of the ration should then be calculated from the recommended DM and DE intakes. Calculating the energy density of the ration facilitates the selection of suitable foods for feeding to donkeys, easing calculation of the ration and reducing the likelihood of donkeys consuming too much or too little energy. Owners aiming to improve or reduce their donkeys body condition can also select foods with a higher or lower energy density than that required for maintenance of body weight.

8.3 SELECTION OF A SUITABLE DIET

The energy density of foods most suited to feeding to mature, healthy donkeys in the UK, which normally have little or no work load, ranged from 6.3 – 6.7MJ DE/kg

DM. The energy and nutrient value of foods vary depending on their species, composition, age when cut or processed, and storage (Chapter 2, 2.2.1 Plant Factors and 2.2.2 Environmental Factors). Ideally foods should be analysed for their energy and nutrient content, however such facilities are not always available. Book values for most feeds offered to equines in the UK are published by NRC (2007). The quality of available forages can also be estimated through visual assessment using a system devised to estimate the energy value of forages for ruminants in the field (Pearson, 2005). The system evaluates forages based on:

- General appearance - is the forage free from mould, dust, rubbish?
  - does it smell fresh and sweet?
- Leaf to stem ratio - is it very fibrous with a lot of stems or young and leafy?
- Colour - is it young, green and fresh cut or old, yellow dry and cut late?

Table 8.1 is then used to score each of the characteristics. Forages with a score under 6 are of poor quality and low energy, whilst those scoring above 12 are classed as good quality, higher energy forages (Pearson, 2005). This system does not give energy values of foods but is useful if no other methods of evaluating foods are available.

Table 8.1. Scoring system used to assess the potential energy value of forages (Pearson, 2005)

	Score				
Characteristic	**1**	**2**	**3**	**4**	**5**
General Appearance	Very poor	Poor	Moderate	Good	Very good
Leaf:Stem ratio	Mainly stems	Stem > Leaf	Stem = Leaf	Stem < Leaf	Very leafy
Colour	Yellow	Yellow > Green	Yellow = Green	Yellow < Green	Very green

Tables 8.2 and 8.3 provide quantities of foods needed to satisfy DE recommendations for maintenance by donkeys in different UK seasons. It must be highlighted once again that the tables provide a starting point from which owners can formulate rations for their individual donkeys. The DE values of the foods used in Tables 8.2 and 8.3 are published book values therefore foods fed to donkeys may vary considerably in their energy value, to that stated in the tables.

8.3.1 Adjustment of Rations for Grazing Access

The recommendations stated above and in Tables 8.2 and 8.3 are based on housed donkeys. The majority of donkeys in the UK are managed with daily access to grazing pasture. Rations and diets must be adjusted to account for the increase in food available and intake of grass.

When managing donkeys using the strip grazing system, the work reported here indicates that providing 140g DM of ungrazed pasture per donkey per day restricts grass intake. A straw intake of 2kg DM per donkey per day was needed to maintain DM and DE intake. Owners wanting to limit their donkeys intake without having to house their donkeys for long periods may find that limiting their donkeys intake of straw to less than 2kg DM per day whilst offering strip grazing of 140g DM or less of ungrazed pasture, reduces intake. When pasture availability exceeds 140g DM per donkey, restricting donkeys to 12 hours or less grazing per day will help to restrict grass intake. When pasture availability decreases below this level, grazing time has little influence on grass intake. In such circumstances energy intake, and therefore body weight, will be influenced by the amount of supplementary forage fed.

Table 8.2. Amount of supplementary forage required during spring, summer and autumn (kg DM/day) by donkeys weighing 100 – 250kg based on 25% of required DE being supplied by supplementary forage

		Food Energy Content (MJ DE/kg DM)										
		Haylage									Chaff: alfalfa based	
			Poor quality hay				Good quality hay					
		Straw				Chaff: straw and hay based						
		5.0	**5.5**	**6.0**	**6.5**	**7.0**	**7.5**	**8.0**	**8.5**	**9.0**	**9.5**	**10.0**
Body Weight (kg)	**100**	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
	110	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
	120	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
	130	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3
	140	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3
	150	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3
	160	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
	170	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4
	180	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4
	190	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4
	200	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4
	210	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.4
	220	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.5
	230	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5
	240	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5
	250	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5

Table 8.3. Amount of supplementary forage required during winter (kg DM/day) by donkeys weighing 100 – 250kg based on 70% of required DE being supplied by supplementary forage

		Food Energy Content (MJ DE/kg DM)										
		Haylage									Chaff: alfalfa based	
			Poor quality hay				Good quality hay					
		Straw				Chaff: straw and hay based						
		5.0	**5.5**	**6.0**	**6.5**	**7.0**	**7.5**	**8.0**	**8.5**	**9.0**	**9.5**	**10.0**
Body Weight (kg)	**100**				1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0
	110				1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0
	120				1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1
	130			1.9	1.8	1.7	1.5	1.4	1.4	1.3	1.2	1.2
	140			2.0	1.9	1.8	1.6	1.5	1.4	1.4	1.3	1.2
	150			2.2	2.0	1.8	1.7	1.6	1.5	1.4	1.4	1.3
	160			2.3	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.4
	170			2.4	2.2	2.0	1.9	1.8	1.7	1.6	1.5	1.4
	180		2.7	2.5	2.3	2.1	2.0	1.8	1.7	1.6	1.6	1.5
	190		2.8	2.6	2.4	2.2	2.1	1.9	1.8	1.7	1.6	1.5
	200		2.9	2.7	2.5	2.3	2.1	2.0	1.9	1.8	1.7	1.6
	210		3.0	2.8	2.6	2.4	2.2	2.1	2.0	1.8	1.7	1.7
	220		3.1	2.9	2.6	2.5	2.3	2.1	2.0	1.9	1.8	1.7
	230		3.2	3.0	2.7	2.5	2.4	2.2	2.1	2.0	1.9	1.8
	240		3.3	3.1	2.8	2.6	2.4	2.3	2.2	2.0	1.9	1.8
	250		3.4	3.2	2.9	2.7	2.5	2.4	2.2	2.1	2.0	1.9

Blank: amount of forage required exceeded DMI of 1.5% BW. Forage of higher DE content required.

When using the set stocking system the provision of 0.02ha per donkey, with a herbage mass of between 1.50 and 1.75kg DM per donkey per day, was adequate to maintain donkeys only if straw was provided. By reducing grazing area, herbage mass, or the amount of straw provided, owners could reduce their donkey's intake whilst allowing donkeys continued grazing access. The reduction of grazing area per donkey, however, would increase the parasitic burden on the pasture, decrease the area donkeys have to exercise, and possibly increase the chances of donkeys becoming injured due to increased contact between animals. Maintaining the grazing area but decreasing the herbage mass, whilst regulating the amount of straw offered, would increase the foraging effort for donkeys, potentially increasing the distance walked each day, increasing the amount of energy expended.

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APPENDICES