

APPENDICES

Appendix 1: Equations used to calculate the UFC and NE value of foods fed to equids (Chapter 2).

UFC value of Foods

Calculation of UFC value of foods (UFC/kg DM) from their chemical composition (Martin-Rosset *et al.*, 1994):

Forages

$$\text{UFC} = 0.0557 + 0.0006 \times \text{CC} + 0.2489 \times \text{DE}$$

$$\text{UFC} = 0.825 - 0.0011 \times \text{CF} + 0.0006 \times \text{CP}$$

Concentrates

$$\text{UFC} = -0.134 + 0.0003 \times \text{CF} - 0.0004 \times \text{CP} + 0.0003 \times \text{CC} + 0.3160 \times \text{DE}$$

$$\text{UFC} = -0.730 - 0.0007 \times \text{CP} + 0.00057 \times \text{OM} + 0.3944 \times \text{DE}$$

Where:

CC: Cytoplasmic carbohydrates

DE: Digestible energy

CF: Crude fibre

CP: Crude protein

OM: Organic matter

All values are g/kg DM

NE value of Foods

The NE value of foods can be estimated using the following equations (Martin-Rosset *et al.*, 1994):

Net energy value of a food is calculated from its GE value, the digestibility of energy (dE), the ratio between ME and DE, and from the efficiency of ME utilisation for maintenance (km).

Gross energy should ideally be measured using bomb calorimetry. Digestibility of energy should be calculated using the following equation:

$$\text{dE} = 0.0340 + \Delta + 0.9477 \times \text{dOM}$$

Where:

Δ : +1.1 for concentrates

- 1.1 for forages

dOM: digestible organic matter (g/kg DM)

The ME content of a feed is calculated for the DE value through the ME/DE ratio. The ME:DE ratio can be predicted using nutrient fractions CF, CP and CC and from the equations below:

Forages and concentrates

$$100 (\text{ME/DE}) = 84.07 + 0.165 \times \text{CF} - 0.276 \times \text{CP} + 0.184 \times \text{CC}$$

The efficiency of ME utilisation for maintenance (km) can be predicted from the chemical composition of the food. Selection of equation used will depend on the nutritional information known about the food;

Forages

$$100 \text{ km} = 57.56 - 0.0110 \times \text{CF} + 0.0105 \times \text{CP} + 0.0270 \times \text{CC} + 0.0150 \times \text{DOM}$$

$$100\text{km} = 71.64 - 0.0289 \times \text{CF} + 0.0148 \times \text{CP}$$

Concentrates

$$100\text{km} = 94.41 - 0.0237 \times \text{OM} - 0.0022 \times \text{CP} + 0.0121 \times \text{CC}$$

$$100\text{km} = 92.27 - 0.0248 \times \text{CF} - 0.0160 \times \text{CP}$$

Where:

DOM: Digestible organic matter

OM: Organic matter

All values are g/kg DM

The NE value of feeds is calculated using the following equation:

$$\text{NE (UFC/kg DM)} = \text{ME} \times \text{km}/2250$$

Appendix 2: Questionnaire used to gather information on husbandry practices, formulated into an A4 booklet (Chapter 3).

1. Owner's Details

Name: _____
Address: _____

Phone Number: _____
Email Address: _____
Preferred method of contact: _____

2. Donkey Details

Name: _____
Age: _____
Sex: Entire male Gelded male Female
Height: _____ cm
Length: _____ cm

3. Health

Please identify any previous and on going health problems using the table below. Use the 'other' and 'additional notes' sections to identify further health problems or provide further information you feel may be of relevance or to verify no known health problems whilst the donkey has been in your care.

Conditions	Previously	On going
Dental Problems	<input type="checkbox"/>	<input type="checkbox"/>
Colic	<input type="checkbox"/>	<input type="checkbox"/>
Hyperlipaemia	<input type="checkbox"/>	<input type="checkbox"/>
Laminitis	<input type="checkbox"/>	<input type="checkbox"/>
Respiratory Problems	<input type="checkbox"/>	<input type="checkbox"/>
Other:	<input type="checkbox"/>	<input type="checkbox"/>

Additional Notes _____

4. Premises Details

Please indicate the primary purpose of the premises where the donkey is kept.

Private Farm Equine

(For Office Use Only)	Recording Period	Jan	Feb	Mar	Apr	May	Jun
Reference Number: _____							
Owner's Name: _____		Jul	Aug	Sep	Oct	Nov	Dec
Donkey's Name: _____							

DONKEY NUTRITION SURVEY

1. Management Details

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

* Stabled – no outside access

** Yarded – free to access shelter if desired, but no access to pasture

Management System	Month 1	Month 2	Month 3
Stabled *	hrs	hrs	hrs
At grass	hrs	hrs	hrs
Yarded **	hrs	hrs	hrs

1.2 When stabled, what type of bedding is provided?

Straw Shavings Woodchip
 Paper Cardboard Not applicable

Other: _____

1.3 Does your donkey eat bedding material?

Yes No Not applicable

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

Yes No Not applicable

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

Other: _____

2. Feeding Regime

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

* Oat Straw / Barley Straw / Hay / Haylage / Other – please state

Delete as appropriate

Name of feed *	Type of feed #	Source #	Sample Taken	Brand and Company Name (if applicable)
1.	Forage/ concentrate	Home grown / locally produced / commercially produced	Yes / No	
2.	Forage/ concentrate	Home grown / locally produced / commercially produced	Yes / No	
3.	Forage/ concentrate	Home grown / locally produced / commercially produced	Yes / No	
4.	Forage/ concentrate	Home grown / locally produced / commercially produced	Yes / No	
5.	Forage/ concentrate	Home grown / locally produced / commercially produced	Yes / No	
6.	Forage/ concentrate	Home grown / locally produced / commercially produced	Yes / No	
7.	Forage/ concentrate	Home grown / locally produced / commercially produced	Yes / No	
8.	Forage/ concentrate	Home grown / locally produced / commercially produced	Yes / No	

2.2 Use the table below to indicate the type and quantity of food fed and the frequency of feeding for each recording period.

Recording Period	Name of feed	Total amount of feed per day (kg)	Number of feeds per day
Month 1	1.		
	2.		
	3.		
	4.		
	5.		
	6.		
	7.		
	8.		
Month 2	1.		
	2.		
	3.		
	4.		
	5.		
	6.		
	7.		
	8.		
Month 3	1.		
	2.		
	3.		
	4.		
	5.		
	6.		
	7.		
	8.		

Appendix 3: Guidelines for completion of questionnaire of husbandry practices, formulated into an A5 booklet (Chapter 3).

**GUIDELINES FOR COMPLETION OF THE
QUESTIONNAIRE AND PRACTICAL
ACTIVITIES FOR DONKEY NUTRITION
SURVEY**

INCLUDING HOW TO COMPLETE

- **OWNER AND DONKEY DATA**
- **QUESTIONNAIRE**
- **RECORDING DONKEY MEASUREMENTS**
- **COLLECTION OF SWARD AND FOOD SAMPLES**

Owner and Donkey Data

SECTION 1. OWNER'S DETAILS

- Personal Information – check this information is correct and make any necessary changes.

SECTION 2. DONKEY DETAILS

- Name and age – check this information is correct and make any necessary changes.
- Sex – place a tick in the box appropriate to your donkey.
- Height – enter your donkey's height in cm measured from the point of withers to the ground when the donkey is stood on a level surface with all four feet square underneath its body. See Donkey Measurements.
- Length – enter your donkey's length in cm measured in a straight line from the pin bone to the elbow when the donkey is stood on a level surface with all four feet square underneath its body. See Donkey Measurements.

SECTION 3. HEALTH

- Place a tick in the boxes appropriate to the health problems your donkey has suffered. Where your donkey has suffered a health problem not listed please provide details of condition suffered and if it is an ongoing or previous condition in the 'other' section of the table or the 'additional notes' section.
- If there are no health problems, please state 'no health problems' in the 'additional notes' section.

SECTION 4. PREMISES DETAILS

- Purpose of premises - place a tick in the box that best describes the purpose of the premises where your donkey is kept.

Questionnaire

SECTION 1. MANAGEMENT DETAILS

- 1.1** Write the number of hours your donkey spends in each management system during the three months of the season. The months being recorded are expressed in the top right hand corner of the page by a line in the appropriate months box.
- 1.2, 1.3** Place a tick in the appropriate box or state alternative bedding used in the 'other' section.
- 1.4** Place a tick in the appropriate box. If the answer is yes enter a number in the appropriate species box or state alternative species and their number in the 'other' section.
- 1.5** Enter the area of grazing available to your donkey per day and delete the unit of measurement as appropriate. If an alternative unit of measurement is used state the area and unit in the 'other' section.
- 1.6** If grazing is restricted indicate the method used and by how much per day. Delete where appropriate.

For example:

Method		Month 1
Time (Hrs/day)		3
Strip Graze (fresh grass – meters/day)		
Size	Acres /	

- 1.7** For each month indicate how often any of the pasture management techniques are carried out. If rotation of livestock is used please state the species used for rotation.
- 1.8** Place a tick in any of the boxes appropriate to your grazing pasture.
- 1.9** Place a tick in any of the boxes appropriate to the borders of your grazing pasture.

- 1.10 For each month place a tick in the box that best describes the quantity of each of the assessment criteria present in your donkey's allocated daily grazing.

SECTION 2. FEEDING REGIME

- 2.1 In the table state the name of the different feeds you have fed your donkey during the three months, and identify the type and source of each feed and if a sample was taken.

For example:

Name of feed *	Type of feed #	Source #	Sample Taken	Brand and Company Name (if applicable)
1. Hay	Forage / concentrate	Home-grown / locally produced / commercially produced	Yes / No	
2. Chaff	Forage / concentrate	Home-grown / locally produced / commercially produced	Yes / No	Fibre Chaff, D & H
3. Horse & Pony Cubes	Forage / concentrate	Home-grown / locally produced / commercially produced	Yes / No	HDF Horse and Pony cubes, Spillers

- 2.2 In each month write the name of each type of feed fed, the total amount of feed fed and the number of feeds per day.

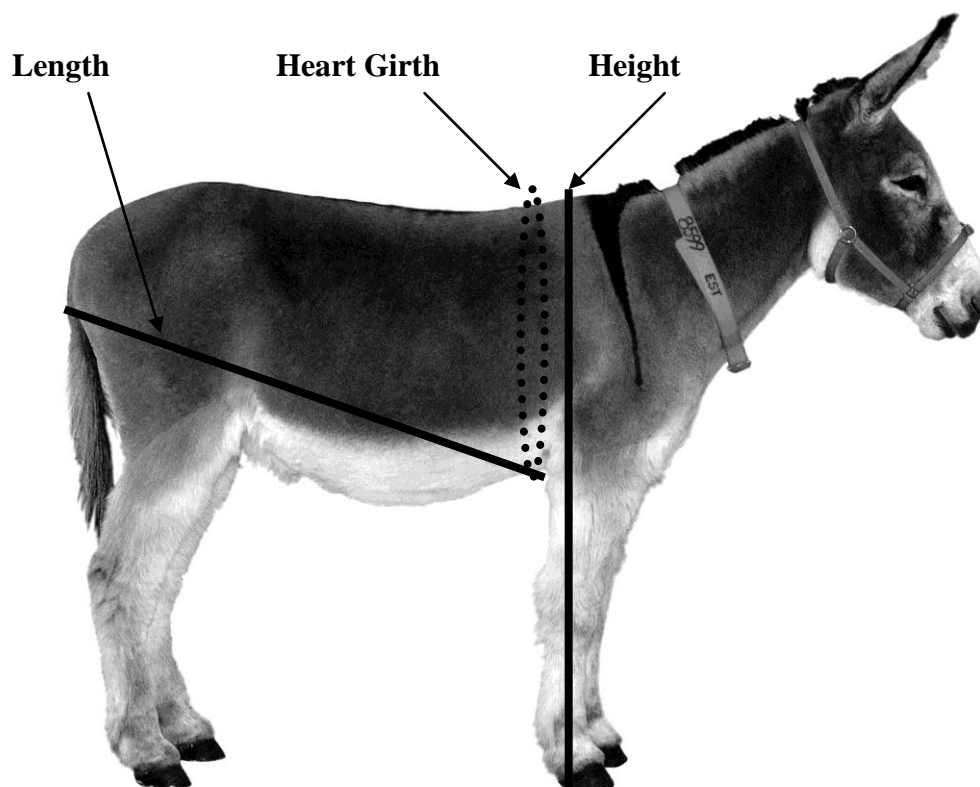
For example:

Recording Period	Name of feed	Total amount of feed per day (kg)	Number of feeds per day
<i>Month 1</i>	1. Hay	2	2
	2. Horse and Pony Nuts	0.5	2
	3.		
	4.		
	5.		

SECTION 3. DONKEY REQUIREMENTS

- 3.1 On a set date each month record your donkey's heart girth and condition score.
- 3.2 For each month place a tick in the section appropriate to your donkey's feeding needs. If in work, state the duration of work carried out by your donkey (hours/week).

Recording Donkey Measurements



Condition Score - See 'Donkey Body Condition Score Chart UK'.

Collection of Pasture and Food Samples

PASTURE SAMPLING

<i>Equipment Provided</i>	A pair of sharp scissors for gathering samples. Sample bags and labelling pen. Quadrat.
<i>Equipment Required</i>	Bucket for collection of samples.
<i>Frequency</i>	Sampling should be carried out in the final week of each season.
<i>Sample Area</i>	The sample area is the area of pasture your donkey has access to at the time of sampling.
<i>Method</i>	Randomly throw the quadrat onto the grazing pasture and collect a grass sample. Repeat this process in another area of the pasture chosen at random, resulting in 2 pasture samples. If strip grazing, samples should be taken of the fresh grass to be offered to your donkey on the sample day. Throw the quadrat at 2 random intervals along the fence line onto the fresh pasture being offered to your donkey and take samples as previously directed.
<i>Taking a Sample</i>	Hold the grass stems vertical away from the soil. Carefully cut the base of the grass approximately 2cm above soil level to prevent any soil contaminating the grass sample. Once collected, place into the bucket and continue. Once both samples are gathered, gently mix the samples together in the bucket. Then take approximately 5 handfuls of grass and place into the sample bag, seal and attach completed labels. Dry the sample on the day of collection as directed in the 'Drying Samples' section.

Additional Notes Samples should not be taken from areas where water logging or bare soil is present.
Samples of weeds and moss should also be avoided.
Samples should be kept out of direct sunlight and once dried should be returned to the address below as soon as possible.

FOOD SAMPLES

Equipment Required Sample bags and labelling pen

Frequency Sampling should be carried out in the final week of each season.

Taking a Sample

Forage	For each different type of forage fed take 2 handfuls from the centre of the bale and place within the sample bag.
Concentrate	For each different type of concentrate feed, take 2 handfuls of food, avoiding the food at the very top of the bag and place within the sample bag.

Seal and attach completed labels. For concentrate samples complete brand and company name.

Drying of hay, straw, chaff and concentrate feeds is not necessary – store these samples in individual labelled airtight bags.

Haylage samples should be dried on the day of collection as directed in the ‘Drying Samples’ section.

Additional Notes Avoid taking samples of any damp or mouldy foodstuffs.
Samples should be kept out of direct sunlight and once dried (if necessary) returned to the address below as soon as possible.

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Post Graduate Room 110
Easter Bush
Roslin
Midlothian, Scotland
EH25 9RE

Drying Samples

Equipment Required Microwave Oven / Conventional Oven
Microwave / oven safe dishes
Scissors

Method Cut each grass / forage sample into inch long pieces and place into an individual shallow ovenproof dish (if drying more than one sample at a time label each dish for identification). Dry sample following the drying guidelines and the health and safety precautions outlined below.

Health and Safety Precautions

- Always follow the oven manufactures safety and operating instructions.
- Choose a dish of suitable material for the oven/microwave.
- Handle dried samples with care as they may become hot during drying.
- If using a microwave oven do not leave samples unattended as samples may ignite if they become too hot.

Drying Samples

If using a conventional oven to dry samples it is advisable to take all forage and pasture samples on the same day and dry all samples at the same time to reduce the length of time the oven has to be used.

Use the guidelines below to dry samples

Oven			
Microwave		Conventional – none fan oven	
	Grass	Haylage	Haylage
Temperature / Wattage	700	700	100oC / gas mark 3
Drying Procedure	60 second drying, 30 seconds rest, 30 – 45 seconds drying *	20 – 30 seconds drying *	Dry over night, minimum of 12 hours drying
Test – to see if dry	Feel dry and crispy to the touch, stems and leaves snap easily	Feel dry and crispy to the touch, stems and leaves snap easily	Feel dry and crispy to the touch, stems and leaves snap easily

* Drying times may vary depending on how wet the fresh sample is – drier samples will require less time than those of greater moisture content.

Appendix 4: Ration composition of donkeys used in the digestible energy study
(Chapter 4).

Summer

Donkey	Fresh Weight (kg)					
	BW (kg)	% BW	Ration (kg DM)	Hay Fresh Weight (25%) @ 85% DM	Straw Fresh Weight (75%) @ 90% DM	Total Ration
Oliver Cald	221	1.75	3.87	1.14	3.22	4.36
Holly Cald	207	1.75	3.62	1.07	3.02	4.08
Blackbury Olive Winnie	187	1.50	2.80	0.82	2.33	3.15
Columbus A	172	1.50	2.58	0.76	2.15	2.91
Jester A	168	1.50	2.52	0.74	2.10	2.84
Stardust A	143	1.50	2.14	0.63	1.78	2.41
John Bp	211	1.75	3.69	1.09	3.08	4.16
Cyril	183	1.50	2.75	0.81	2.29	3.09
Penny Jones	194	1.50	2.90	0.85	2.42	3.27
Shirgar Martin	179	1.50	2.69	0.79	2.24	3.03
Benny Pearson	198	1.50	2.97	0.87	2.48	3.35
Prancer Jay Eire	206	1.50	3.09	0.91	2.58	3.48
Dawny (mona) Eire	191	1.50	2.87	0.84	2.39	3.23
Foaly Eire	169	1.50	2.53	0.74	2.11	2.85
Bob Ruane Eire	197	1.50	2.95	0.87	2.46	3.32
Lucky RSPCA	191	1.50	2.86	0.84	2.38	3.22
Seven RSPCA	208	1.75	3.64	1.07	3.03	4.10
Smokey Staff	165	1.50	2.48	0.73	2.06	2.79
Rachel F				Not used in study		
Sophie F				Not used in study		

Autumn

Donkey	Fresh Weight (kg)					
	BW (kg)	% BW	Ration (kg DM)	Hay Fresh Weight (25%) @ 85% DM	Straw Fresh Weight (75%) @ 90% DM	Total Ration
Oliver Cald	221	1.75	3.87	1.14	3.22	4.36
Holly Cald	207	1.75	3.62	1.07	3.02	4.08
Blackbury Olive Winnie	187	1.50	2.80	0.82	2.33	3.15
Columbus A	172	1.50	2.58	0.76	2.15	2.91
Jester A	168	1.50	2.52	0.74	2.10	2.84
Stardust A	143	1.50	2.14	0.63	1.78	2.41
John Bp	195	1.75	3.41	1.00	2.84	3.85
Cyril	183	1.50	2.75	0.81	2.29	3.09
Penny Jones	194	1.50	2.90	0.85	2.42	3.27
Shirgar Martin	179	1.50	2.69	0.79	2.24	3.03
Benny Pearson	185	1.50	2.78	0.82	2.31	3.13
Prancer Jay Eire	206	1.50	3.09	0.91	2.58	3.48
Dawny (mona) Eire	191	1.50	2.87	0.84	2.39	3.23
Foaly Eire	169	1.50	2.53	0.74	2.11	2.85
Bob Ruane Eire	185	1.50	2.77	0.81	2.31	3.12
Lucky RSPCA	191	1.50	2.86	0.84	2.38	3.22
Seven RSPCA	208	1.75	3.64	1.07	3.03	4.10
Smokey Staff	165	1.50	2.48	0.73	2.06	2.79
Rachel F				Not used in study		
Sophie F				Not used in study		

Winter

Donkey	Fresh Weight (kg)					
	BW (kg)	% BW	Ration (kg DM)	Hay Fresh Weight (70%) @ 85% DM	Straw Fresh Weight (30%) @ 90% DM	Total Ration
Oliver Cald	211	2.5	5.22	4.30	1.74	6.04
Holly Cald	199	2.5	4.93	4.06	1.64	5.70
Blackbury Olive Winnie	174	2.5	4.31	3.55	1.44	4.98
Columbus A	Not used in study					
Jester A	160	2.5	3.96	3.26	1.32	4.58
Stardust A	138	2.5	3.42	2.81	1.14	3.95
John Bp	190	2.5	4.70	3.87	1.57	5.44
Cyril	Not used in study					
Penny Jones	183	2.5	4.53	3.73	1.51	5.24
Shirgar Martin	174	2.5	4.31	3.55	1.44	4.98
Benny Pearson	181	2.5	4.48	3.69	1.49	5.18
Prancer Jay Eire	196	2.5	4.85	3.99	1.62	5.61
Dawny (mona) Eire	178	2.5	4.41	3.63	1.47	5.10
Foaly Eire	162	2.5	4.01	3.30	1.34	4.64
Bob Ruane Eire	Not used in study					
Lucky RSPCA	171	2.5	4.23	3.49	1.41	4.90
Seven RSPCA	196	2.5	4.85	3.99	1.62	5.61
Smokey Staff	160	2.5	3.96	3.26	1.32	4.58
Rachel F	168	2.5	4.16	3.42	1.39	4.81
Sophie F	147	2.5	3.64	3.00	1.21	4.21

Spring

Donkey	Fresh Weight (kg)					
	BW (kg)	% BW	Ration (kg DM)	Hay Fresh Weight (50%) @ 85% DM	Straw Fresh Weight (50%) @ 90% DM	Total Ration
Oliver Cald	211	2.00	4.22	2.48	2.34	4.83
Holly Cald	199	2.00	3.98	2.34	2.21	4.55
Blackbury Olive Winnie	174	2.00	3.48	2.05	1.93	3.98
Columbus A				Not used in study		
Jester A	160	2.00	3.20	1.88	1.78	3.66
Stardust A	138	2.00	2.76	1.62	1.53	3.16
John Bp	190	2.00	3.80	2.24	2.11	4.35
Cyril	173	2.00	3.46	2.04	1.92	3.96
Penny Jones	183	2.00	3.66	2.15	2.03	4.19
Shirgar Martin	174	2.00	3.48	2.05	1.93	3.98
Benny Pearson	181	2.00	3.62	2.13	2.01	4.14
Prancer Jay Eire	196	2.00	3.92	2.31	2.18	4.48
Dawny (mona) Eire	178	2.00	3.56	2.09	1.98	4.07
Foaly Eire	162	2.00	3.24	1.91	1.80	3.71
Bob Ruane Eire	174	2.00	3.48	2.05	1.93	3.98
Lucky RSPCA	171	2.00	3.42	2.01	1.90	3.91
Seven RSPCA	196	2.00	3.92	2.31	2.18	4.48
Smokey Staff	160	2.00	3.20	1.88	1.78	3.66
Rachel F	168	2.00	3.36	1.98	1.87	3.84
Sophie F	147	2.00	2.94	1.73	1.63	3.36

Appendix 5: Linear regression of donkey body weights against experimental day, for gelded and female donkeys during each season (Chapter 4).

Results of linear regression analysis of body weight versus experimental day for gelded male and female donkeys during each season, calculated using Minitab 15.

Season	Sex	Equation	r^2	Significance of effect
Period 1 Summer	Geldings	BW = 190kg – 181g/day	0.8%	NS
	Females	BW = 187kg – 231g/day	1.2%	NS
Period 2 Autumn	Geldings	BW = 180kg – 124g/day	0.2%	NS
	Females	BW = 177kg – 147g/day	0.3%	NS
Period 3 Winter	Geldings	BW = 174kg + 163g/day	0.7%	NS
	Females	BW = 167 + 133g/day	0.4%	NS
Period 4 Spring	Geldings	BW = 179 + 13g/day	0.0%	NS
	Females	BW = 168 + 8g/day	0.0%	NS

Appendix 6: Publications of the research findings of this thesis.

- a) Wood, S.J., Smith, D.G., & Morris, C.J. (2005). Seasonal variation of digestible energy requirements of mature donkeys in the UK. *Proceedings of the 3rd Equine Nutrition Conference*, Hanover, Germany. 1st – 2nd October 2005. pp 39-40.
- b) Wood, S.J., Smith, D.G., Morriss, C.J., Oliver, J., & Cuddeford, D. (2006). The effect of pasture restriction on dry matter intake of foraging donkeys in the UK. *Proceedings of the 5th International Colloquium on Working Equines*, Addis Ababa, Ethiopia. 30th October – 2nd November 2006. pp 285-295.
- c) Wood, S.J., Smith, D.G., Muir, C.J., & Cuddeford, D. (2006). Seasonal variation of digestible energy requirements of mature donkeys in the UK (poster presentation). *Proceedings of the 5th International Colloquium on Working Equines*, Addis Ababa, Ethiopia. 30th October – 2nd November 2006. pp 250-259.
- d) Smith, D.G., & Wood, S.J. (2008). Nutrition. In: J. Duncan & D. Hadrill (Ed.), *The Professional Handbook of the Donkey* (4th ed.). London, Whittet Books.

Appendix 6a

Seasonal variation of digestible energy requirements of mature donkeys in the UK

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Introduction

Acute and chronic overfeeding of equines is a major cause of poor welfare in the United Kingdom, resulting in sudden fatalities caused by diseases like hyperlipaemia (Fowler 1995), or premature euthanasia due to conditions such as laminitis and colic (Crane 2000). Donkeys are particularly susceptible to this abuse as they are mostly kept as companion animals with few, if any, work demands. The problem of overfeeding donkeys is further exacerbated by the lack of information distinguishing their nutritional requirements from those of horses and ponies. This absence of specific feeding recommendations forces owners and professionals to draw upon feeding guidelines already developed for horses. Taylor (2000) suggests donkey feeding requirements on a body weight basis are 0.75 of those published for horses. However, it is not known if these recommendations over estimate nutritional demand and subsequently add to the problem of over weight donkeys.

The formation of feeding recommendations begins with the calculation of energy requirements for maintenance, as this is the value to which other nutrients are related. A number of studies have been carried out into the energy requirements of donkeys, although their focus has primarily been on the energy demands of working donkeys transporting loads over various distances and terrain (Yousef and Dill 1969, Pearson et al. 2001, Ram et al. 2004). Values for dry matter intake (DMI) and digestible energy (DE) intake by donkeys at rest are quoted in a number of studies (Pearson and Merritt 1991, Cuddeford et al. 1995, Ram et al. 2004) however these studies only observed small numbers of animals over short periods of time. No study has been carried out to determine the DE requirements of donkeys for maintenance during the different seasons of the UK climate.

The aim of this study was to determine the maintenance digestible energy requirements of mature donkeys during summer and winter.

Materials and methods

The study took place between May 2003 and July 2004 at The Donkey Sanctuary, Sidmouth, Devon, UK. Two recording periods took place; the first between June and August 2003 and the second between December 2003 and February 2004. During recording periods the donkeys were housed in individual stables and received individual hay and barley straw rations in quantities that were adjusted to maintain body weight. An equilibrium period of 25 days was followed by a 5 day total faecal collection.

Animals

20 mature donkeys, 10 male, 10 female were selected for the study. 10 male (159-217kg) and 8 female (139-203kg) donkeys were used during the summer recording period and 7 male (157-210kg) and 10 female (133-200kg) donkeys during the winter period. The donkeys were weighed daily using a weigh bridge and the mean weekly body weight calculated.

Sample collection and laboratory analysis

Daily samples of food offered were taken for the last 7 days of each recording period. Samples of food refused and faeces were taken daily for each donkey for the last 12 and 5 days of each recording period, respectively, and pooled for each donkey. All samples were dried at 60°C to determine dry matter, and retained for laboratory analysis. Dried samples were ground using a hammer mill through a 1mm screen. Food offered and faecal samples were analysed for neutral-detergent fibre (NDF), acid-detergent fibre (ADF), crude protein (CP), gross energy (GE) and organic matter (OM) according to the methods reported by the Association of Official Chemists (1990). Daily dry matter, digestible energy and digestible crude protein intakes were calculated for each donkey.

Results

Body weight

Body weights remained stable throughout the study. Small losses occurred in the summer season whilst weight gain occurred in winter. The weight gain coincided with an increased hay ratio in the ration resulting in significantly greater DM and DE intakes ($P < 0.001$) (See table 2).

Climate

Mean daily temperature during each recording period was 6°C and 20°C for summer and winter, respectively.

Diet composition, digestibility and intake

Diet composition is shown in table 1. The hay and straw fed in summer contained higher GE, NDF and ADF levels than those fed in winter. These higher NDF and ADF levels are reflected in the low DMI and DMD during the summer. CP levels for the hay fed in both seasons and the straw fed in winter are lower than those of published values (McDonald et al. 1995) and reflect low quality forage.

Daily DM, DE and DCP intakes are shown in table 2. Sex had no significant effect on any results obtained ($P > 0.05$). The increased hay: straw ratio in the

winter ration resulted in a significant ($P<0.01$) increase in DMD and is reflected by the increase in DM (g/kg BW) and DE (kJ DE/kg BW) intakes during the winter ($P<0.001$). The largest increase was seen in DE intake despite the lower energy value of the winter diet. Digestible crude protein (DCP) intakes were also significantly ($P<0.01$) higher in winter.

Table 1. Composition and energy density of diets offered (g/kg DM unless otherwise stated)

		Season	
		Summer	Winter
Hay	DM (g/kg)	920.6	901.8
	GE (kJ/kg DM)	15500	14900
	OM	963.6	971.5
	CP	52.8	44.0
	NDF	774.9	648.7
	ADF	401.1	370.7
Straw	DM (g/kg)	925.3	919.0
	GE (kJ/kg DM)	16100	15300
	OM	978.8	979.1
	CP	51.7	32.6
	NDF	879.3	846.5
	ADF	549.2	493.1
% Straw in ration		75	30
% Hay in ration		25	70
Energy content of rations (kJ DE/kg DM)		6900	6700

Table 2. Mean (\pm s.e.) DM, DE and DCP intakes and dry matter digestibility (DMD) by males and female donkeys during summer and winter.

		Season				Significance of effect of	
		Summer	s.e	Winter	s.e	sex	Season
DM (kg/day)	Males	2.40	0.04	3.28	0.05	NS	***
	Females	2.23	0.04	2.89	0.05		
DM (g/kg BW)	Males	12.9	0.35	18.4	1.28	NS	***
	Females	12.3	0.70	17.5	1.00		
DE (KJ/day)	Males	16819	964	20970	1057	NS	**
	Females	15238	1269	20000	1356		
DE (KJ/kg BW)	Males	90.0	3.4	122.0	8.1	NS	***
	Females	85.0	7.6	117.0	6.5		
DCP (g/day)	Males	42.30	3.87	45.10	3.48	NS	**
	Females	33.60	4.11	53.50	7.24		
<i>in vivo</i> DMD of diets (\pms.e)							
	Males	0.47	0.01	0.50	0.01	NS	***
	Females	0.46	0.02	0.54	0.02		

NS: not significant, * $P<0.05$, ** $P<0.01$, *** $P<0.001$

Discussion

The lack of importance, socially in developing countries and economically in countries such as the UK, has resulted in only limited amounts of research into the donkey compared to that into the horse. The absence of feeding recommendations specific to donkeys results in them being fed as small horses. However, recent studies comparing the digestive efficiency of donkeys to that of other domestic equines have shown that donkeys are superior at digesting high fibre foods (Cuddeford et al. 1995; Pearson and Merritt 1991), and therefore probably require lower intakes.

Comparison of results from this study with NRC (1989) recommendations for ponies of the same body weight show the donkeys required considerably less daily DM, DE and DCP intakes for maintenance in both summer and winter. DMI was 64 and 69% and DE intake was 54 and 74% of recommendations for summer and winter, respectively. The greater increase in DE intake during winter was achieved by increasing the hay ratio in the ration, therefore increasing the digestibility of the diet. CP intakes were also lower than NRC (1989) recommendations for both seasons despite low apparent digestibility. Comparison of these results with those from other studies is difficult due to the mixed ration fed here, although it is evident that the donkeys in this study had lower DM, DE and DCP intakes than those in previous studies (Pearson and Merritt 1991, Pearson et al. 2001, Ram et al. 2004).

Conclusions

These results show donkeys require less than 0.75 of horse rations that is currently recommended as a guide to feeding donkeys (Taylor, 2000). It is also evident that a diet of low energy value is most suitable for feeding to donkeys to enable them to satisfy DMI requirements without consuming excess energy.

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Appendix 6b

THE EFFECT OF PASTURE RESTRICTION ON DRY MATTER INTAKE OF FORAGING DONKEYS IN THE UK.

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Abstract

*Measuring daily food intake of foraging animals is essential if accurate feeding rations are to be implemented. The alkane technique, which has recently been validated in equines, now provides the opportunity to measure intake at pasture. The aims of this study were to determine the effects of herbage mass and grazing time allowance on dry matter intakes in mature donkeys in the UK. The effect of grazing time allowance on diet composition was also measured. Two study periods took place; period 1 when pasture was sparse (herbage mass $133.1 \pm 10 \text{ g/m}^2$) and period 2 when pasture was more abundant (herbage mass $284.5 \pm 17.2 \text{ g/m}^2$). Twenty mature donkeys (10 male, 10 female) were selected for the study and split into three grazing groups. Groups 1 and 2 were restricted to 8 and 12 hours grazing time per day, respectively. Group 3 was allowed 23 hours grazing time daily. Access to a yarded area and shelter was available to all donkeys during grazing periods. Barley straw was fed *ad libitum* to all donkeys and was available at all times. Each donkey was administered with 150mg per day of an n-alkane marker Dotriacontane (C32) in the form of a labelled wheat biscuit fed three times daily for the 12 days of each study period. During period 1 grazing time allowance had no significant effect on daily DMI although the donkeys with 23 hours access did consume more than donkeys with only 12 and 8 hours grazing access (2.61, 2.54 and 2.26 kg, respectively). The proportion of grass and straw comprising daily intake was affected by grazing time allowance ($P < 0.05$). Grass comprised 18% of daily intake for the 8 and 12-hour groups and 11% in the diet of the 23-hour group, although this difference was not significant. During period 2 daily DMI remained unaffected by grazing time allowance. The proportions of grass and straw within the diet were significantly affected ($P < 0.001$), grass comprised 25 and 29% of daily intake for the 8 and 12-hour groups but made up 41% of daily intake of the 23-hour group. These results show that grazing time allowance has little effect on overall DMI but when given the opportunity donkeys increase their grass intake.*

Introduction

Food availability affects intake with food shortages preventing appetite and nutrient satisfaction and abundances promoting nutrient excesses. Seasonal variations in food availability require animals to regulate their intake to maintain energy balance and satisfy nutrient requirements through adjustment of feeding mechanisms and behaviour. Under domestic situations the quality of available food is generally regulated by those managing the animal. When housed and fed specific quantities maximum intake is also regulated allowing nutrient intakes to be calculated. When fed *ad libitum* and when grazing some degree of food selection (plant species, plant

part) and regulation of intake will be exhibited by the animal. Calculation of nutrient intakes in these circumstances is difficult, although essential, if accurate feeding rations are to be implemented. In situations where grazing resources are limited and nutrient demands are not satisfied, additional food rations, either in the form of forages or concentrates, must be supplied to ensure good health and maintain body condition. In situations where grazing is abundant intakes must be limited to prevent excessive weight gain and the health problems associated with increased body condition – colic (Frape, 2004), laminitis (Reilly, 2000) and hyperlaemia (Reid and Mohammed, 1996).

Studies into the affect of herbage availability on DMI of grazing equines are extremely limited and there have been no published findings involving donkeys. Naujeck and Hill (2003) and Naujeck *et al.* (2005) investigating grazing horses found DMI increased as herbage mass (g/m^2) increased. These results however are probably more closely related to sward height (cm) and density (g/cm^3) as these characteristics have been shown to influence grazing behaviour and food intake in grazing ruminants (Gordon *et al.*, 1996; Barrett *et al.*, 2001) and equines (Hughes and Gallagher, 1993; Naujeck and Hill, 2003). Herbivores also adapt to changes in herbage availability and sward characteristics by adjusting their time allocated to grazing. Ruminants (Allden and McDWhittaker, 1970; Gekara *et al.*, 2001) and horses (McMeniman, 2003) increased grazing time in response to grazing shorter swards compared to grazing times on taller swards. McMeniman (2003) reported similar DMI for different sward heights despite increased grazing times on shorter swards. Increasing grazing time enables some degree of compensation for decreased bite depth and weight incurred on shorter swards however this compensatory behaviour will be limited by the maximum time available to graze. In support of this theory are the findings by Iason *et al.* (1999) that grazing sheep, despite increasing intake rate (mg/minute), were unable to fully compensate for restricted grazing time resulting in lower DMI (kg/day) than sheep with continual access to grazing. Smith (1999) investigating grazing behaviour and DMI in cattle and donkeys found donkeys restricted to 8 and 11 hours grazing per day had lower DMI ($\text{g/kg BW}^{0.75}$) than donkeys with 24 hours grazing access. The higher DMI of the 24 hour group were attributed to longer access time as bite rates, although higher in the 8 hour group, were not significantly different between grazing groups resulting in similar intake rates and lower DMI.

The aims of this study were to determine the effects of herbage mass and grazing time allowance on dry matter intakes (DMI) in mature donkeys in the UK. The effect of grazing time allowance on diet composition was also measured.

Materials and Methods

Experimental Design

The study took place on Donkey Sanctuary premises, Sidmouth, Devon, UK (Latitude +50.7016, longitude -3.1918, grid reference SY 1585 8985). The study consisted of two experimental periods; period 1 represented the end of the summer grazing season when available pasture was sparse (25th August – 26th September 2003), period 2 represented the start of the grazing season when pasture was abundant (18th May – 18th June 2004). Each recording period consisted of an

adaptation phase (20 days) allowing the donkeys to become accustomed to their management routine and an experimental phase (12 days) when an *n*-alkane marker was administered and food and faecal samples were taken.

Animals and Management

20 mature donkeys, 10 male, 10 female, were selected for the study. 10 male (starting body weights 164 – 216kg) and 8 female (145 – 208kg) donkeys were used during the first experimental period and 9 male (160 – 208kg) and 10 female (138 – 205kg) donkeys during the second experimental period. The donkeys were weighed using a weighbridge (Horseweigh, Powys, Wales, UK) at the same time daily for the duration of the study. The donkeys were managed in three grazing groups. Groups 1 and 2 were restricted to 8 and 12 hours grazing time per day, respectively. Group 3 was allowed 23 hours grazing per day. The same grazing area (1.5 acres) was used for the three groups resulting in all donkeys grazing together for 8 hours per day. The amount of fresh ungrazed pasture available to the donkeys was regulated by strip grazing using an electric fence. The length of the electric fence was moved approximately 1 meter per day exposing fresh ungrazed pasture. Access to a yarded area with shelter, water and barley straw (*ad libitum*) was available to all donkeys at all times. 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.

N-alkane Marker Preparation, Administration and Analysis

Preparation

Wheat biscuits approximately 5cm in length were chosen as the method for administering the *n*-alkane Dotriacontane C32 to the donkeys. 25g of C32 was dissolved in 2 litres of heptane in a large conical flask. 2ml of the alkane/heptane solution was transferred to each wheat biscuit and the heptane allowed to evaporate. This process was repeated until each wheat biscuit contained 4ml (50mg of C32) of heptane solution. The biscuits were then oven cooked for 24 hours at 70°C to ensure complete absorption of the alkane and evaporation of the heptane.

Administration

For the last 12 days of each experimental period each donkey received 3 wheat biscuits per day (7:00 13:00 and 20:00 hours) totalling 150mg alkane daily (75mg/100kg BW).

Analysis

Straw, pasture (0.2g per sample) and faecal (0.1g) samples were weighed in duplicate and analysed for their *n*-alkane content as described by Ali *et al.* (2004, 2005). DMI was calculated using equation 1 described by Dove and Mayes (1991). Diet composition was determined using the EatWhat software package.

Equation 1.

$$\text{Daily DMI (kg DM)} = \left(\frac{F_i}{F_j} * D_j \right) / \left(H_i - \frac{F_i}{F_j} * H_j \right)$$

Where

F_i – faecal odd chain alkane concentration

F_j – faecal even chain alkane concentration

H_i – forage odd chain alkane concentration

H_j – forage even chain alkane concentration

D_j – daily even chain alkane dose

Sample Collection

Daily samples of the barley straw offered and the fresh ungrazed pasture were taken for last 9 days of each experimental 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°C in a force draft oven to determine dry matter (DM). Dry samples were retained for nutritional analysis. The fresh pasture available to the donkeys was sampled daily using a 30cm² quadrat. Three samples were taken (Top, middle and bottom of the grazing area) at the same time each day prior to being grazed (11:30 when all donkeys restricted to yard area). For each quadrat the pasture was cut to approximately 2cm above soil level and placed in a metal dish of known weight. Each sample was 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.

One complete faecal deposit per donkey was collected daily for the last 5 days of each experimental period. Each deposit was mixed thoroughly in a clean bucket and a subsample taken (~250g, 5% of average 5kg wet weight faecal deposit). Subsamples were frozen until the end of each experimental period to prevent fermentation and spoiling. At the end of each period faecal samples were thoroughly defrosted and a subsample taken from each days faecal deposit and pooled on an individual donkey basis. The subsamples were weighed and dried as for straw and retained for nutritional analysis. Prior to analysis all dried samples (straw, pasture and faeces) were ground using a hammer mill through a 1mm screen.

Nutritional Analysis

Straw, pasture and faecal samples were analysed for residual DM, organic matter (OM), gross energy (GE), crude protein (CP), neutral-detergent fibre (NDF) and acid-detergent fibre (ADF) according to the methods reported by the Association of Official Analytic Chemists (1990). *In vitro* DM digestibility (DMD) was determined using the neutral cellulase plus gamanase (NCG) technique described by ANKOM technology.

Statistical Analysis

Statistical significances of difference between treatments were calculated by two-way analysis of variance using Minitab 14.13.

Results

Climate

Daily temperatures were similar for both experimental periods ranging from 11 to 34°C (mean 18°C) for period 1 and from 10 to 27°C (mean 17°C) for period 2. Rain fall was not measured during this study.

Body Weight

Mean body weight changes during the 12 day experimental phase of each study period are shown in table 1. Body weights remained stable during both periods indicating the donkeys were regulating their intake to near maintenance levels.

Table 1. Mean body weights (kg) and body weight changes (g/day) of donkeys in each grazing group during each period.

	Period 1			Period 2		
	Start BW (kg)	End BW (kg)	BW change (g/day)	Start BW (kg)	End BW (kg)	BW change (g/day)
8 hours	187	186	-73	182	186	351
12 hours	167	166	-201	159	163	200
23 hours	199	200	-90	200	202	83

Food Offered

The nutritional content of the barley straw offered and fresh pasture available are shown in table 2. The barley straws fed during both periods were from different harvests but similar in nutrient content and produced the same *in vitro* DMD result. Pasture samples from both experimental periods contained the same amount of GE although CP levels were considerably higher in period 1 than in period 2 indicating the pasture in period 1 contained young plants of greater nutritional value. The slightly higher NDF and ADF levels and the low DMD of the period 1 pasture however conflict this theory indicating more mature, less digestible plants comprised the pasture.

Daily Food Intake

Effect of Grazing Time

During both experimental periods the donkeys grazing for 23 hours per day consumed the most DM (kg/day) although the differences between grazing groups were not significant ($P>0.05$). See table 3. Grazing time also had no significant effect on DMI per kg BW although differences in DMI between grazing groups were greater in period 1 (12.2 – 15.6 g/kg BW) compared to period 2 (15.4 – 15.8g/kg BW). Composition of total daily DMI was affected by grazing time during both periods although with opposite affects. See figure 1. During period 1 donkey's grazing for 23 hours per day ate proportionally less grass than those grazing for 12 and 8 hours per day ($P<0.05$). During period 2, when pasture was more abundant,

grazing time had the opposite affect with donkeys grazing for 23 hours per day consuming proportionally more grass than those grazing for only 12 and 8 hours per day ($P<0.001$). In both periods, regardless of grazing time, all donkeys chose to eat more straw than grass.

Effect of Herbage Mass

Herbage mass significantly affected daily DMI and diet composition. When pasture was more abundant (period 2) the proportion of grass in the diet increased ($P<0.001$) in all grazing groups indicating an effect of pasture availability on diet selection. Total daily DM intakes were on average higher ($P<0.05$) in period 2 although the mean DMI per day of the 12 hour grazing group was slightly lower in period 2 compared to period 1.

Estimated Digestible Energy Intake

Digestible energy (DE) intake was estimated from calculated daily DMI and faecal DM output. See table 3. Results show considerable variation between grazing groups although these differences were not significant ($P>0.05$). Of interest is the slightly higher total daily DE intakes (MJ/day) of the 8 and 12 hours grazing groups in period 1 compared to period 2 despite the lower grass digestibility and content of the diet in period 1. See figure 2.

Table 2. Nutritional composition of foods offered during each period.

	Period 1		Period 2	
	Pasture	Straw	Pasture	Straw
DM (g/kg)	268	884	308	935
GE (MJ/kg DM)	16.9	17.2	16.9	16.4
CP (g/kg DM)	125	33	67	28
NDF (g/kg DM)	677	888	569	806
ADF (g/kg DM)	354	575	318	556
<i>In vitro</i> DMD	0.60	0.37	0.65	0.37

Table 3. Mean daily DMI and estimated digestible energy intake.

Herbage mass \pm s.e. (g/m ²)	Period 1						Period 2						Significance of effect of grazing time herbage mass	
	8		12		23		8		12		23			
Intake	hours	s.e	hours	s.e	hours	s.e	hours	s.e	hours	s.e	hours	s.e		
	133 \pm 10						285 \pm 17.2							
DM (kg/day)	2.26	0.12	2.54	0.24	2.61	0.14	2.95	0.28	2.51	0.19	3.09	0.16	NS	*
DM (g/kg BW)	12.2	0.64	15.6	1.85	13.1	0.55	15.8	1.20	15.5	2.89	15.4	0.87	NS	*
Estimated DE intake (kJ/kg BW)	107	7.8	124	18.1	99	11.2	111	12.7	89	13.1	95	5.9	NS	NS

NS: not significant

* P<0.05

s.e: standard error

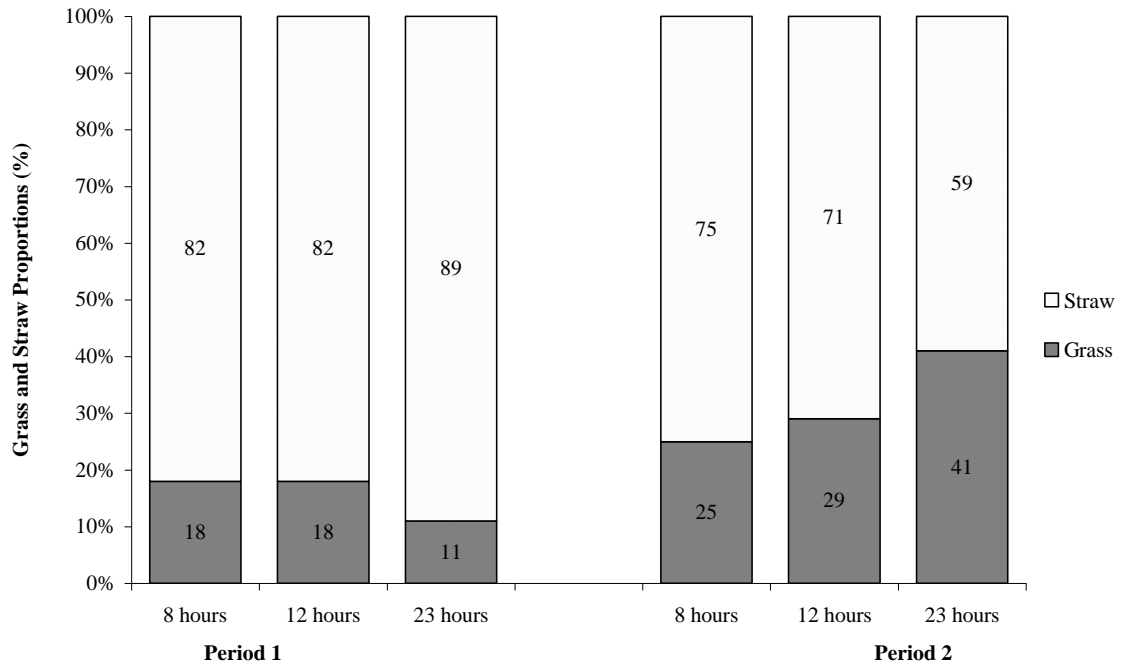


Figure 1. Percentage of grass and straw comprising total daily DMI for donkeys in each grazing group during each period.

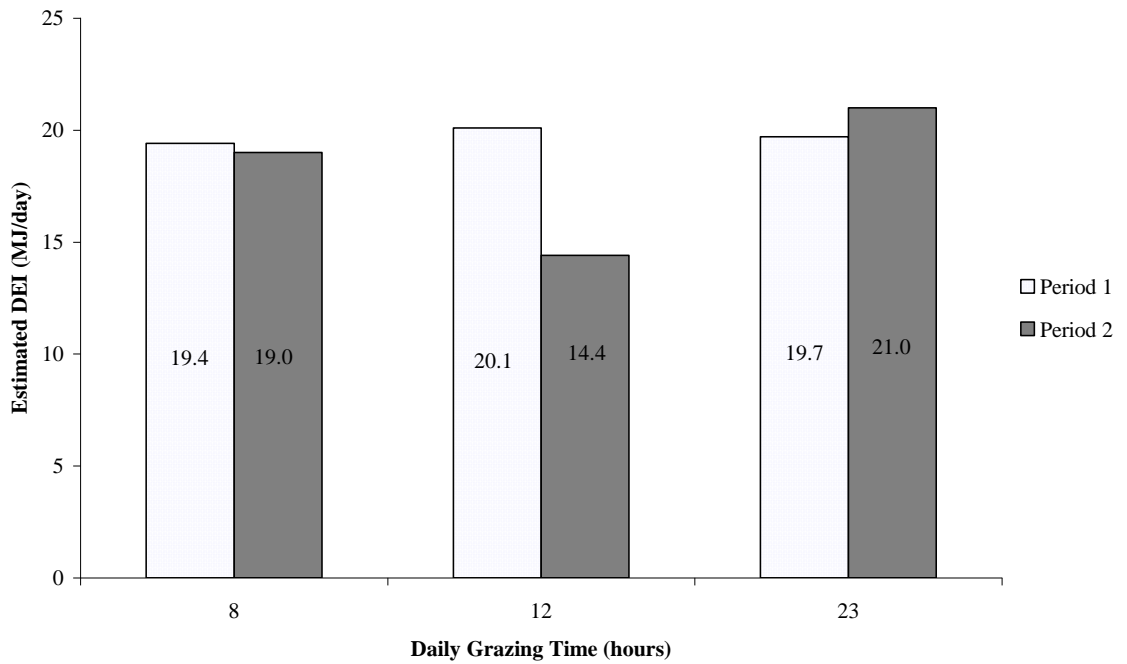


Figure 2. Mean daily DE intake (MJ/day) of donkeys in each grazing group during each period.

Discussion

Daily Food Intake

The stable body weights of the donkeys indicate they were regulating their intake to maintain body condition (NRC, 1981). Comparison of DMI gained in this study with previous work is difficult due to the absence of any published values for grazing donkeys. Comparison with DMI of housed donkeys fed *ad libitum* is also difficult due to the considerable variation in diets offered and results gained. This lack of information on donkey requirements for maintenance make evaluating the effect grazing access has on daily intake and satisfying nutrient requirements difficult. DM and DE intakes of stabled donkeys for maintenance were reported by Muller *et al.* (1994) and Wood *et al.* (2005). Muller and colleagues (1994) feeding grass hay and grass/legume hay reported DM intakes of 19.2 and 18g per kg BW, respectively. Wood *et al.* (2005), studying the effect of season on DM and DE intakes in mature donkeys eating barley straw and hay, reported much lower DM intakes in summer (12.6g/kg BW) but similar intakes in winter (18g/kg BW) to those reported by Muller *et al.* (1994). Results from both periods in this study, also carried out in summer, support the findings by Wood and colleagues (2005). Estimated DE intakes gained here (110 and 98 kJ/kg BW for periods 1 and 2, respectively) are lower than those reported by Muller *et al.* (1994) (168 kJ/kg BW) but slightly higher than the summer DE intakes (88 kJ/kg BW) reported by Wood *et al.* (2005). The higher DE but similar DM intakes in this study are probably due to the higher digestibility of the pasture and therefore higher energy intake per unit of DM eaten. Had the study continued for longer an increase in body weight may have been seen indicating the donkeys were eating above maintenance levels.

Effect of Grazing Restriction and Herbage Mass

Restricting grazing access 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. Restricting grazing time in this study did not reduce total daily DMI due to free access to straw. In situations where grazing is restricted but there is free access to forage results here indicate donkeys are able to compensate for pasture restriction if an alternative forage is provided in adequate quantities. Grazing access does appear to have an effect on diet composition although herbage mass is an influencing factor on how donkeys respond to grazing restriction. When herbage availability was limited (period 1) the donkeys with 23 hours grazing access had the lowest proportion of grass in their diet (11%) compared to the donkeys grazing for 12 and 8 hours per day (18%). This lower percentage of grass in the diet was not expected and could be an affect of the donkeys regulating their own intake resulting in a lower percentage of grass in the diet. Cuddeford and Hyslop (1996) suggested housed equines do not regulate their intakes in the short term. The same may be true of donkeys managed with only limited grazing access (8 and 12 hours per day) resulting in donkeys consuming the most grass possible during their allocated grazing time leading to higher proportions of grass in their diets. Confounding this theory are results for period 2 when herbage was abundant. The percentage of grass in the diet increased as grazing time increased with donkeys grazing for 23 hours per day having significantly higher grass intakes than those grazing for 12 and 8 hours. It would appear that when pasture is available donkeys increase their grass intake at

the expense of straw intake. The high straw content of all diets however suggests donkeys have a requirement for some fibrous foods within their diets. Studies by Archer (1973) and Kelleher (1995) of grazing horses and by Lamoot *et al.* (2005) of grazing donkeys all found fibrous plants were consumed even when there was an ample supply of more nutritious vegetation. In addition wood chewing is a behavioural problem often associated with high concentrate, low fibre diets in horses (Redbo *et al.*, 1998). The high straw content in the diets of donkeys in all grazing groups also suggests that donkeys were unable to satisfy nutrient and DMI requirements on grass alone requiring them to 'fill up' on straw. Despite the higher digestibility of the grass compared to the straw, the low DM content (g/kg) in the grass would have prevented adequate DM and nutrient intakes on grass alone.

Practical Application

Formulating correct feeding rations requires both nutrient demands and daily DMI requirements to be satisfied. In situations where weight gain is a problem restricting daily DMI may reduce the total amount of energy provided but will not satisfy DMI requirements. As a consequence donkeys will continue to eat if food provisions allow, resulting in excess energy intake and continued weight gain. Reducing the time available to graze will help to reduce grass intake and if combined with the feeding of a low energy forage, allow donkeys to satisfy DMI requirement without consuming excess energy. Alternatively grazing donkeys on sparse pastures will also help to manage DMI.

In situations where access to pasture is limited, either due to donkeys working or sparse pasture, feeding alternative food sources *ad libitum* allows donkeys to compensate for limited grass intake. It is unclear however from these results if donkeys regulate their energy intake when fed *ad libitum* and grazing and so the feeding of any high energy concentrate foods should always be monitored.

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Appendix 6c

SEASONAL VARIATION OF DIGESTIBLE ENERGY REQUIREMENTS OF MATURE DONKEYS IN THE UK

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Abstract

At present there are no published feeding guidelines specific to donkeys. Current recommendations are to feed 0.75 of horse energy needs on a body weight basis. However, it has been shown that donkeys have a greater digestive efficiency than horses and ponies and thus, feeding them as though they were small horses results in excess energy intake and, as a consequence they become obese. The formation of feeding guidelines begins with the estimation of the energy requirement for maintenance as this is the value upon which nutrient requirements are related to. The aim of the study was to determine the maintenance digestible energy requirements of mature donkeys during each UK season. Twenty mature donkeys (10 male, 10 female) were selected for use in the study. The donkeys were fed a diet of hay and barley straw in quantities that were adjusted to maintain body weight. An equilibration period of minimum 16 days was followed by a 5 day total faecal collection; this was carried out for each season. Food and faecal samples were analysed for dry matter (DM), organic matter (OM), digestible energy (DE), crude protein (CP), neutral-detergent fibre (NDF) and acid-detergent fibre (ADF); nutrient and energy intakes were calculated. There was a significant seasonal effect on all intakes except NDF and ADF. DM and DE intakes showed significant increases in winter compared to summer, rising by 42 and 35%, respectively. DCP intakes increased during winter and spring but were significantly lower in autumn compared to all other seasons. A strong seasonal effect was exerted on all in vivo digestibilities although there was no effect of sex. OM, NDF and ADF intakes were affected by sex with male animals having higher intakes compared to female animals. Comparison of these results with NRC (1989) horse requirements showed a considerably reduced requirement by donkeys for energy and protein and thus it was concluded that feeding tables specific to horses are not suitable for calculating donkey requirements.

Introduction

Review of the current literature indicates donkeys have greater digestive efficiency than horses and ponies, able to digest foods, particularly high fibre foods, to greater extent (Tisserand *et al.*, 1990; Pearson and Merritt, 1991; Cuddeford *et al.*, 1995; Pearson *et al.*, 2001). This greater efficiency results in greater gain per unit of food, reducing the total amount required to satisfy nutrient demand reflected by lower daily DMI requirements. In studies by Tisserand *et al.* (1990), Pearson and Merritt (1991) and Pearson *et al.* (2001) donkeys consumed on average 21% less DM per kg BW per day than ponies receiving the same hay and straw diets. In each of these studies apparent DMD was higher in the donkeys compared to the ponies. Higher

GE digestibilities by donkeys were also reported in the studies by Pearson and Merritt (1990) and Pearson *et al.* (2001). If energy requirements were similar to those of ponies of equivalent BW the greater GE digestibility would compensate for lower DMI by the donkeys. Digestible energy (DE) intakes per kg BW however were 17% lower than the ponies in the studies by Pearson and Merritt (1991) and Pearson *et al.* (2001). These findings suggest that although the donkey gains more energy per unit of food consumed, the higher GE digestibility does not fully compensate for lower daily DMI indicating that donkeys have lower daily DEI requirements than ponies of equivalent BW.

The apparent ability of the donkey to gain more DE per unit of food than horses or ponies requires owners to be particularly stringent with the amount of food on offer to their donkeys. Housed equines do not appear to regulate their intakes (Cuddeford and Hyslop, 1996) therefore consuming enough food to satisfy nutrient requirements does not trigger satiety. Balancing the ration and choosing a suitable diet is vital to ensure the correct amount of energy is provided whilst appetite is satisfied. The feeding of more energy dense foods will require less DM to be consumed to meet energy demands however the donkey will continue to eat due to feelings of hunger that if continued will lead to increased body weight. Management of animals in over weight condition imposes a welfare issue due to the increased susceptibility of fat animals to joint and respiratory problems (Lewis, 1995). Equines, in particular donkeys and ponies, are also more susceptible to suffer from colic, laminitis, hyperlipaemia and Equine Metabolic Syndrome when in over weight condition (Fowler, 1995; Reid and Mohammed, 1996; Tarrant *et al.*, 1998; Crane, 2000; Reilly, 2000; Frape, 2004; Johnson, 2005). Feeding smaller amounts of high energy foods also reduces the time occupied by eating. For equines, whose natural behaviour is to spend around 16 – 20 hours per day eating (Duncan, 1980), reducing the time occupied by food can result in animals becoming bored and can be particularly problematic when animals are individually stabled due to extended periods of time with nothing to occupy them. Prevention of these health and behavioural problems and any associated suffering requires all equines to be fed suitable diets in correct amounts. However the absence of any feeding guidelines specific to donkeys prevents accurate calculation of their requirements.

In an attempt to fill this gap in nutritional knowledge and provide some guidance to donkey owners, Taylor (2000) proposed using 0.75 of calculated horse requirements. However, it is clear from the findings of previous studies highlighted above that such recommendations are unsuitable due to their blanket reduction on all calculated nutrient requirements. Feeding to satisfy DM and DE requirements may help to prevent excess intakes however deficits in other nutrients may be incurred as a result. The development of donkey specific feeding guidelines will help to prevent the health problems associated with nutrient imbalances, specifically the effects of energy excess in none working donkeys in the UK and other developed countries and nutrient deficits in working donkeys in countries where food resources are limited. An understanding of the donkey's nutritional demands will enable owners to utilise diets available to them to ensure the donkey receives a suitably balanced ration. The first step in formulating donkey specific feeding guidelines is determination of energy requirements for maintenance as this is the value upon which nutrient

requirements are related. The primary aim of the following study was to determine daily maintenance DE requirements of mature donkeys in the UK. DE intakes were calculated for each of the UK seasons to assess for the effect of climate on energy requirements.

Materials and Methods

Experimental Design

The study was carried out between May 2003 and July 2004 at The Donkey Sanctuary, Sidmouth, Devon, UK. During this time four recording periods took place; period 1, summer (4th June – 8th August 2003), period 2, autumn (29th September – 31st October 2003), period 3, winter (15th December 2003 – 9th February 2004), period 4, spring (16th March – 30th April 2004). During the recording periods the donkeys were stabled separately and received individual hay and straw rations. Each recording period was divided into 3 phases; equilibrium, intake recording and 5 day total faecal collection. Prior to the start of each recording period the donkeys were adapted to eating out of feeding troughs within their stables. Between recording periods the donkeys were managed and fed as a group, and allowed access to pasture during the summer months.

The equilibrium phase lasted 20 days in summer and spring, 19 days in winter and 9 days autumn. Individual rations offered were adjusted to equal that consumed and stabilise donkey body weights. Intake recording and total faecal collection took place concurrently over the final 13 and 6 days of each recording period, respectively. Collection of all food refused and faecal deposits started at 09:30 on the first day of each phase and continued until 09:30 on the last day of each recording period, resulting in 12 days intake recording and 5 days total faecal collection.

Animals and management

20 mature donkeys, 10 male, 10 female were selected for the experiment. 10 male and 8 female donkeys were used during the summer and autumn recording periods, 7 male and 10 female donkeys during the winter period and 9 male and 10 female donkeys during the spring recording period. The donkeys were weighed using a weighbridge (Horseweigh, Powys, Wales, UK) at the same time daily for the duration of the study. During the recording periods the donkeys were housed in individual stables (7.6 m²) within a large open-span barn. Each stable had a wooden corner feeding trough and an automatic water drinker. Rubber matting covered by none edible bedding (Easibed, GI Hadfield & Sons Ltd) 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. An indoor loafing area (151m²) and outside concrete yard provided space for the donkeys to interact and socialise between feeding times. During faecal collection phases the donkeys were allowed into the loafing area at designated times when staff were available to observe for any faecal deposits. Between recording periods the donkeys were housed as a group in the loafing area and yard.

Feeding and diet

A diet of hay and barley straw was fed throughout the experiment. The donkeys received their ration in 3 meals per day, receiving 25% of the ration in meals 1 and 2 and the remaining 50% in meal 3. The donkeys received a ration of 1.5 – 1.75, 2.5 and 2% body weight, at hay: barley straw ratio of 25:75, 70:30 and 50:50, for summer and autumn, winter and spring, respectively.

Sample collection

Daily samples of food offered were taken for the last 7 days of each recording period. Grab samples were taken from each new hay and straw bale opened and stored in individual airtight bags. For each forage, samples were pooled and chopped into approximately 5cm lengths. A subsample was then taken, weighed and dried at 60°C in a force draft oven to determine DM. Dry samples were retained in airtight bags for nutritional analysis.

Total daily food refusals and faecal deposits were stored in separate bags for each individual donkey. Collection of all food refused and faecal deposits for the previous 24 hours were complete before the feeding of meal 1 at 09:30. The fresh weight of total food refused and faecal deposits were recorded daily for each donkey and a sample taken of each (~ 250g). Samples were weighed and dried as for food offered and retained in airtight bags for nutritional analysis. Prior to analysis the dried faecal samples for each donkey were pooled and all dried samples were ground using a hammer mill through a 1mm screen.

Nutritional analysis

Food offered and faecal samples were analysed for neutral-detergent fibre (NDF), acid-detergent fibre (ADF), crude protein (CP), gross energy (GE) and organic matter (OM) according to the methods reported by the Association of Official Analytic Chemists (1990).

Calculations

For the 5 day total faecal collection phase daily DM digestibility (DMD), DM intake (DMI), DEI and digestible crude protein (DCP) intake were calculated. Daily DMI was calculated by the difference between ration DM offered and total daily refusal DM. Daily faecal DM output was calculated as total fresh faecal output multiplied by faecal DM content. The resulting DM intakes and outputs were used to determine daily DE and DCP intakes. Endogenous nitrogen losses in the faeces were accounted for using equation 1 taken from Frape (2004).

Equation 1.

$$\text{Endogenous Nitrogen (N)} = 3\text{g N / kg DM intake}$$

Statistical analysis

Statistical significances of difference between treatments were calculated by two-way analysis of variance using Minitab 14.13.

Results

Climate

Mean daily temperatures during each season were 15, 10, 4 and 7°C for summer, autumn, winter and spring, respectively. Rainfall was not recorded for this study.

Body Weight

The aim of the experiment was to calculate energy requirements for maintenance therefore it was imperative that donkeys maintained a constant weight for the duration of the study. Daily fluctuations in body weight due to gut fill or defecation were accounted for by a 5kg fluctuation margin. Female donkeys were generally in lighter body weight than male donkeys during all seasons. Maintenance of body weight within 5kg of start weight was not achieved for females during summer and males and females during winter. Small losses in body weight were incurred in summer and autumn resulting in average total losses of 4.8 and 7.1kg during summer and 1.6 and 4.6kg during autumn for males and females, respectively. Increases in body weight during winter (6.1 and 5.9kg, males 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 ratio in the ration (See table 2). Body weights during spring were more stable for both male and female donkeys than in any other season reflected by less than a kilogram change between average body weights at the start and end of the season. Despite these seasonal variations comparison of body weights at the end of each season showed no significant difference ($P > 0.05$).

Diet Composition and Digestibility

Rations offered and diet compositions are shown in table 1. Changes in the straw: hay ratio offered each season resulted in significant differences in nutrient apparent digestibilities ($P < 0.001$). Increasing the hay content of the winter ration to almost reverse of that offered in summer increased the digestibility of DM but had no effect on OM, GE and CP digestibility. The winter ration also resulted in the lowest NDF and ADF digestibilities although NDF utilisation was similar to that on the high straw autumn ration. Also of note is that 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 ($P < 0.001$) OM, GE and CP digestibilities. There was no effect of sex on apparent digestibilities ($P > 0.05$).

Table 1. Ration composition and nutrient content of diets offered during each season (g/kg DM unless otherwise stated).

Diet Offered		Season			
		Summer	Autumn	Winter	Spring
Hay	DM (g/kg)	921	903	902	913
	GE (MJ/kg DM)	15.5	14.9	14.9	14.3
	OM	964	991	972	954
	CP	53	45	44	64
	NDF	775	648	649	688
	ADF	401	364	371	444
Straw	DM (g/kg)	925	924	919	929
	GE (MJ/kg DM)	16.1	15.9	15.3	15.3
	OM	979	973	979	973
	CP	52	38	33	29
	NDF	879	854	847	840
	ADF	549	606	493	634
% Straw in ration		75	75	30	50
% Hay in ration		25	25	70	50
DE content of ration (MJ/kg DM)		6.9	6.0	6.7	6.2

Food Intake

Mean daily DM (g/kg BW), DE (kJ/kg BW) and DCP (g/day) intakes during each season are shown in figure 1. 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. The combination of food refusals and the relatively stable body weights show rations did not restrict the donkey's intakes and the donkeys were eating for maintenance. All refusals consisted of straw.

Season had a significant effect ($P < 0.001$) on DM, DE and DCP intakes. DMI was similar in summer and autumn and autumn and spring but significantly higher in winter than all other seasons ($P < 0.001$). The lowest DM intakes (g/kg BW) were in summer however the lowest DE (kJ/kg BW) 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 nutrients per unit of food consumed. Increasing the hay ratio in the winter ration enabled significantly higher DM, OM and DE intakes ($P < 0.001$). There was no effect of sex on DM, DE or DCP intake ($P > 0.05$).

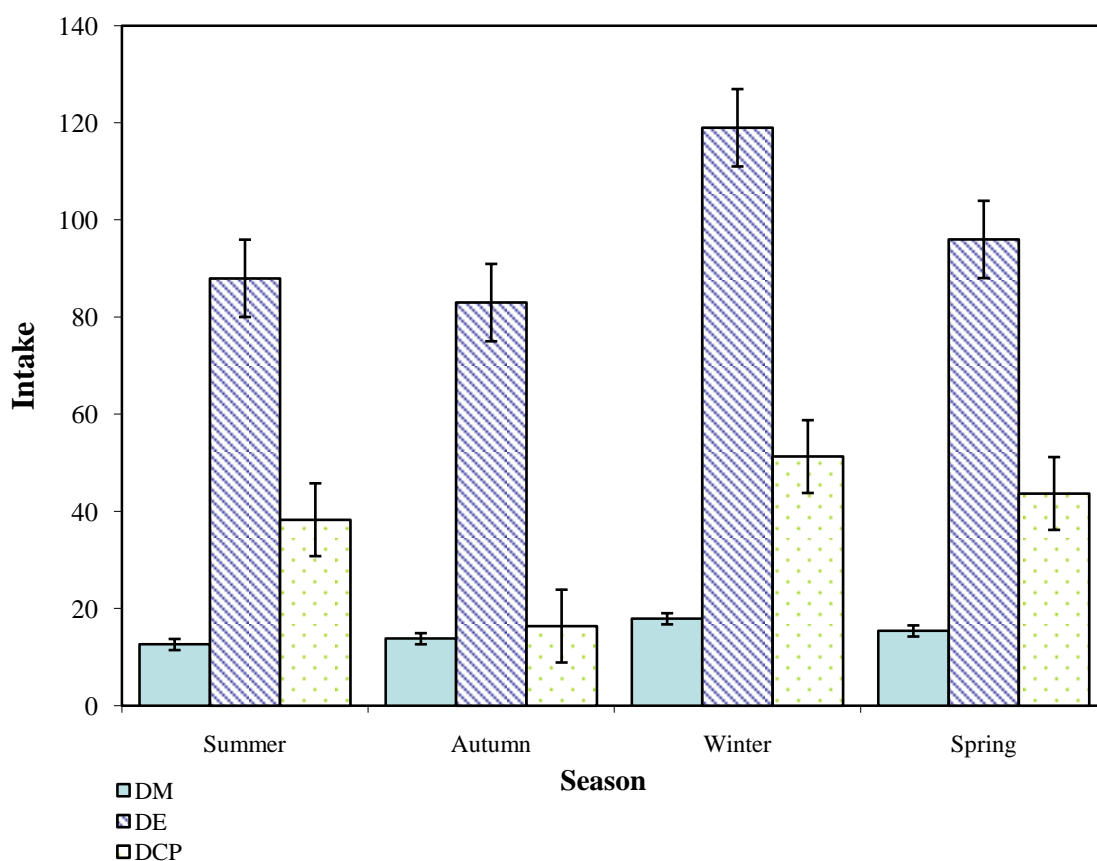


Figure 1. Mean daily DM (g/kg BW), DE (kJ/kg BW) and DCP (g/day) intakes during each season.

Comparison between donkey intakes and current horse recommendations (NRC, 1989)

Voluntary daily DMI for horses is estimated at 15 – 25g per kg BW (NRC, 1989). Results show daily DMI by donkeys were in the lower end of this scale ranging from 13g/kg BW in summer to 18g/kg BW in winter. Autumn (14g/kg BW) and spring (15g/kg BW) intakes were at the lower end of this range.

Average seasonal DE intakes for donkeys during each period and calculated DE requirements using current horse recommendations (NRC, 1989) are shown in figure 2. Estimated DE requirements were calculated using the mean body weight of each donkey each season and the seasonal average for all donkeys was used to compare *in vivo* results with calculated estimates. The relatively stable body weights of the donkeys resulted in little variation in calculated DE requirements although *in vivo* DEI varied significantly ($P < 0.001$). DE intakes by the donkeys were 56, 52 and 58% of calculated requirements for summer, autumn and spring, respectively. Only in winter did DEI increase to current feeding recommendations for donkeys (75% of horse requirements, Taylor, 2000).

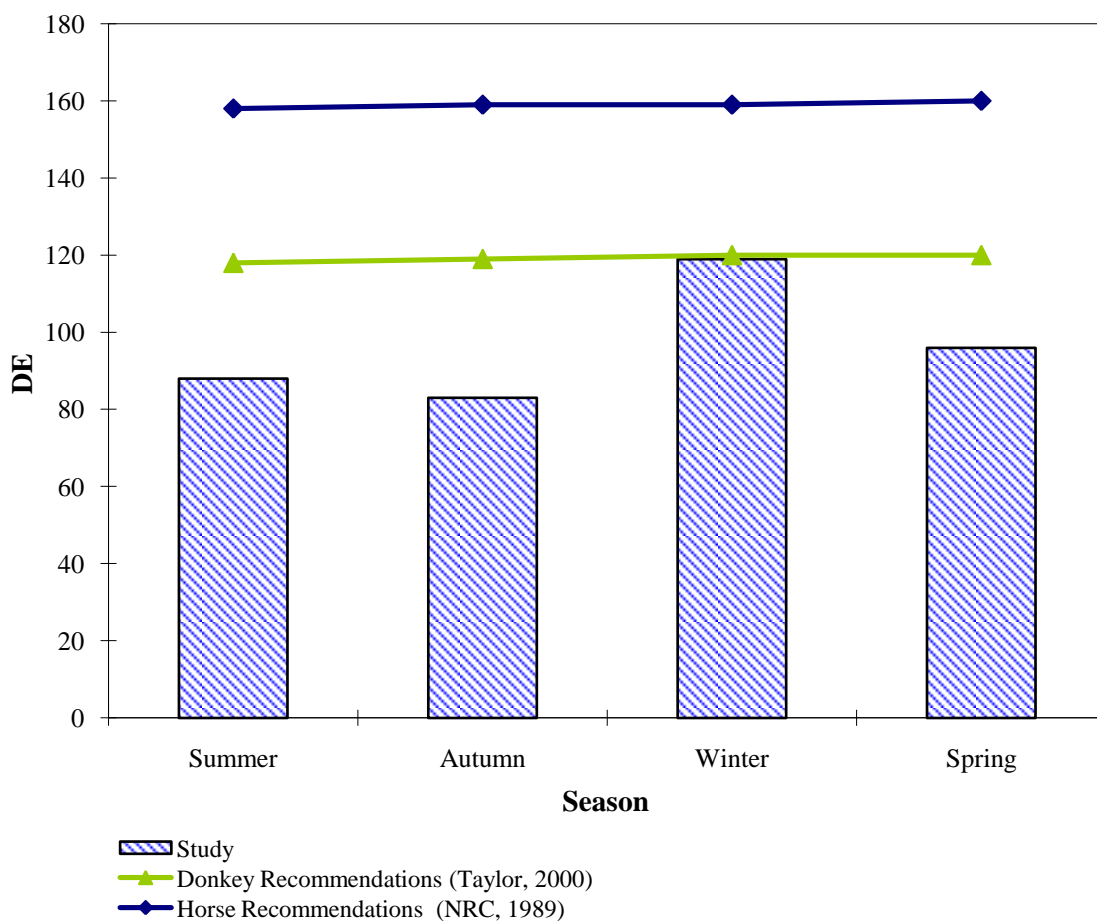


Figure 2. Comparison of daily *in vivo* DEI with current horse recommendations (NRC, 1989) and current donkey recommendations (Taylor, 2000) during each season (kJ/kg BW)

Discussion

The donkey lacks social importance in developing countries and economic value in countries such as the UK. This insignificance of the donkey has resulted in only limited amounts of research into the needs of donkeys compared to the increasing understanding of the requirements of horses and livestock. In the area of nutrition there have been a number of investigations comparing the digestive efficiency of the donkey to that of ponies, horses and ruminants with DE and DCP intakes being reported as a consequence of these studies (Pearson and Merritt, 1991; Cuddeford *et al.*, 1995; Pearson *et al.*, 2001). No study has investigated the DE requirements of donkeys specifically for maintenance preventing the composition of feeding tables explicit to donkeys. As a result owners are forced to use current donkey guidelines based on scaled down horse calculations recommended by Taylor (2000). These recommendations are based on findings that donkeys have greater digestive efficiency than horses and ponies (Pearson and Merritt, 1991; Cuddeford *et al.*, 1995) and therefore gain more nutrients per unit of DM eaten however the suitability of these recommendations is unknown. Under- and over-estimates of nutritional requirements can have deleterious effects on animal health although feeding unsuitable energy levels has perhaps the most obvious symptoms. Chronic over

feeding of energy results in increased adipose stores, weight gain and eventual obesity (Lewis, 1995), whilst prolonged energy deficits require mobilization of body fat stores and loss of body condition. Donkeys in the UK are most commonly kept as companion animals with little if any work demands. They are frequently managed with access to lush pasture plus preserved forages and/or concentrates (S.J, Wood, unpublished data). This ample supply of food plus limited amounts of exercise frequently result in over weight donkeys with increased susceptibility to health problems such as colic, laminitis and hyperlipaemia (Fowler, 1995). Prevention of such health problems requires regulation of energy intake and formulation of correct feeding rations.

Results obtained here show donkeys require significantly less DM (g/kg BW) and DE (kJ/kg BW) than horses of equivalent BW and that there is a strong seasonal affect on their requirements for maintenance. Current horse recommendations are based on the 1989 publication by The National Research Council (NRC, 1989). Using these calculations and each donkey's average BW comparisons between estimated horse requirements and actual donkey intakes can be made. On average donkeys in this study required 39% less DE per kg BW than estimated using NRC (1989) calculations. Based on the findings here current feeding guidelines for donkeys (Taylor, 2000) also appear to overestimate DE requirements for donkeys during all seasons except winter (DEI were 74, 69, 99 and 80% of recommended DE requirements for donkeys for summer, autumn, winter and spring, respectively (Taylor, 2000). Maintenance of BW in winter required the hay portion of the ration to be increased resulting in significantly ($P<0.001$) greater DMI and DMD. Increasing the hay ratio in winter resulted in lower ($P<0.001$) NDF and ADF digestibilities but had no affect on digestibility of OM, GE and CP. This reduction in utilisation of fibrous fractions but lack of effect on soluble fractions indicates that increasing the hay portion in the winter increased passage rate and enabled higher DMI.

DM and DE intakes gained here were lower in summer and autumn than those previously reported for donkeys receiving high straw diets (Cuddeford *et al.*, 1995) and all straw diets *ad libitum* (Tisserand *et al.*, 1990, Pearson *et al.*, 2001) and at restricted levels (70% *ad libitum*) (Pearson *et al.*, 2001). Mean DM and DE intakes of donkeys receiving a diet of alfalfa hay and oat straw in a similar ratio to that fed in summer, were 14.3 g/kg BW and 142 kJ/kg BW, respectively (Cuddeford *et al.*, 1995). The higher energy value of the hay and straw compared to that fed here resulted in a considerably higher energy intake. Tisserand *et al.* (1990) also reported a DMI of 14.3 g/kg BW for donkeys receiving molassed wheat straw *ad libitum*, whilst Pearson *et al.* (2001) reported higher DMI when feeding chopped molassed oat straw (*ad libitum*). DEI in the study by Pearson and colleagues (2001) however was lower than that reported by Cuddeford *et al.* (1995) but was still higher than that reported here for all periods. The higher intakes in these previous studies can be attributed to higher gross energy levels in diets and greater apparent DM digestibilities compared to that reported here (0.47). Winter DMI (g/kg BW) in this study were considerably higher than those reported for donkeys offered alfalfa hay and oat straw in similar proportions to that fed here in winter (Cuddeford *et al.*,

1995). DE intakes however were lower in this study due to the lower GE content of the hay and straw fed here.

From this study it is clear that donkeys in the UK require less digestible energy per kg of BW to satisfy maintenance requirements compared to horses and ponies. These findings are in agreement with previous research although these results are the first to identify the effect of colder temperatures on energy requirements in donkeys. During summer donkeys require approximately half the amount of energy needed by a pony of the same weight, with a low energy dense diet being most suitable in order to satisfy appetite without over feeding energy. During colder temperatures energy and protein demands increase significantly compared to summer although they remain considerably lower than those of horses and ponies. Even with this increased energy demand, a diet high in fibre and of low energy density remains the most suitable. It can be concluded from these results that feeding tables specific to horses are not suitable for calculating donkey requirements and that further research into the seasonal effect on nutrient requirements in all equines, not just donkeys, would be advantageous, allowing more accurate estimates of demand to be calculated.

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Appendix 6d

Donkey nutrition

David Smith and Stephanie Wood

The donkey's natural feeding patterns

Under feral conditions donkeys will spend virtually all the hours of daylight and some of the night (14-16 hours per day) foraging for food. They are highly selective feeders and, when allowed to roam freely in their natural environment, dedicate a lot of time to finding preferred morsels before eventually resigning themselves to eating less palatable fodder. When donkeys are brought into human care these natural conditions are difficult to replicate, especially under temperate conditions where fodder is abundant and often of high quality. Moreover, donkeys are more efficient at digesting food than horses and, as a consequence, can thrive on less forage than a similar-sized pony. The challenge for keepers is to provide donkeys with enough food to keep them busy in their favourite activity (eating) but not to allow them to become obese, which puts them at risk of developing serious and often fatal diseases such as hyperlipaemia and laminitis.

The structure of the donkey's gut

The structure and function of the donkey's gut is remarkably similar to that of the horse, with no obvious physical features that account for its superior efficiency. The intestine of the donkey is ~24 metres long and has a total maximal capacity of ~160 litres. However, the total volume of gut contents rarely exceed a third of the maximal capacity. Starting at the mouth, ingested food passes via the oesophagus to the stomach (~9% of total gut capacity), small intestine (~30% of total capacity), caecum (~16% of total capacity), colon (~38% of total capacity) and rectum (~7% of total capacity) to the anus where after 24-35 hours it is evacuated as faeces.

One way in which donkeys adapt to high fibre diets (such as straw) is to use the full capacity of their large intestine (caecum and colon) so forage can be retained for longer and be digested more thoroughly. This increased capacity of the large intestine gives straw-fed donkeys a 'pot' belly, which conspires with their angular body frame to give the appearance of ill thrift. Consequently, donkey keepers should use the body condition scoring systems developed by The Donkey Sanctuary (summarised at the end of this chapter) as a guideline to the fatness of their donkeys rather than relying on the often-deceptive visual appearance. Body condition scoring systems developed for horses should not be applied to donkeys, because the two species store fat in different parts of their bodies.

Upon consumption food must be converted into a form that can be readily absorbed and used by the body to meet nutritional demand. Prior to absorption, any complex structures must be digested into simple soluble forms by the combined processes of physical and chemical breakdown.

Physical breakdown

Before digestion can start, donkeys must first physically breakdown their food by the action of chewing. Every kilogram of hay that the donkey consumes requires to be chewed more than 2000 times in order to reduce the forage to fragments of approximately 1.6 mm in length. These small fragments are much more readily digested than larger particles and allow the donkey to make efficient use of its food. Concentrated feeds require less chews per kilogram (1000 –1500) whilst poorer quality feeds like straw require more chews per kilogram (2500+). The condition of the teeth has a large effect on the efficiency of chewing; donkeys with large molar protrusions and sharp hooks on their teeth will spend longer chewing and chew less efficiently than a donkey with a flat molar table. Keepers should keep a carefully eye on the condition of their donkey's teeth, especially in mature donkeys (more than 5 years' old) that have all their permanent teeth. Donkeys over 10 years' old should have their teeth rasped at least once a year by a qualified equine dentist, and the frequency of rasping will need to increase as the donkey gets older. Quidding (ejection of partly chewed food from the mouth) and long fibres (or whole grains) in the faeces are signs of advanced dental problems. Checking the donkey's mouth should be an essential routine part of any veterinary examination carried out on working donkeys bought to mobile clinics. A few minutes spent rasping the teeth of a working donkey can make an immeasurable long-term improvement to its tough life. Checking and recording the condition of donkey's teeth at the time of purchase or adoption is also advisable because it provides a baseline observation to which future examinations can be compared.

Chemical breakdown

In donkeys, there are two distinct processes of chemical breakdown of food. These are referred to as digestion and fermentation (also called degradation). Digestion is a process where enzymes (digestive chemicals) produced by animal tissues breakdown food. Fermentation is a process where enzymes produced by microbes (bacteria, protozoa and fungi) break down food and the animal uses the end products of these reactions as a source of nutrients. The animal provides the microbes with a favourable place to live and plenty of food. In return the microbes provides the animal with the energy-rich end products of fibre breakdown, which otherwise would be unavailable. This is known as a symbiotic relationship between organisms.

The nature of donkeys' food

The plant cells that make up most of the food that donkeys eat consist of two main fractions - cell contents and cell wall material (or fibre). Plant cell contents are highly digestible and very nutritious, but diminish rapidly in quantity as plants mature. The fibre component consists mainly of three different carbohydrates; hemicellulose, cellulose and lignin. When young the plant cell wall is made up mainly of easily digestible hemicellulose (digestible fibre) but with age the amount of cellulose and lignin (indigestible fibre) in the cell wall increases. Consequently the fibre component becomes less digestible as the plant ages. Cellulose is broken down by microbes in the large intestine (caecum and colon) of the donkey by the process of fermentation. Without these microbes donkeys would not be able to

make use of fibrous foods like straw and hay. Lignin is a woody substance that is virtually undegradable even by gut microbes.

Spring pasture is rich in plant cell contents and low in fibre, and is therefore very nutritious, but as the summer progresses the amount of fibre increases and the cell contents diminish, particularly as the grasses come into flower. The conserved forages that are fed to donkeys are generally quite mature when harvested (hay, haylage and straw) and have a relatively small amount of cell contents compared to the levels of fibre.

Water requirements

On average about 60% of the donkey's body is made up of water, about 82% of the blood volume is water and even 25% of the weight of bone is water. Every biological reaction of the body requires water as a solvent. Water is required to move nutrients and oxygen around the body to where they are needed and to remove waste products to the lungs and kidneys. Water deprivation depresses appetite and therefore reduces the intake of other essential nutrients. In terms of the rapidity of the development of deficiency symptoms, water is probably the single most important nutrient. However, it is the one which is most often overlooked, with keepers often underestimating a donkey's daily requirement for water or not appreciating an animal's reluctance to drink from containers contaminated with urine, faeces, saliva or algal slime.

Donkeys have evolved in semi-arid environments and are well adapted to cope with thirst and rapid rehydration. They are able to tolerate and quickly recover from body water losses of up to 30% of their normal body weight, then rehydrate rapidly by drinking 24-30 litres of water in 2-5 minutes without ill effect. Donkeys are more thirst tolerant than ponies, and will maintain food intake even when deprived of water for long periods. However, this short-term tolerance of thirst should not be confused with the long-term requirement for water.

The overall water requirement of donkeys is similar to that of horses. The general rule is that animals should always be provided with free access to clean water throughout the day. The best way to provide this is by self-filling water troughs that should be regularly cleaned. Providing water in buckets is hard work for the keeper and the buckets are highly likely to be contaminated or knocked over unless secured by some means. When donkeys are used for work they should be given frequent opportunity drink during the working day and given free access to water during the night.

Energy requirements

Donkeys derive a principal source of their energy from non-structural carbohydrates (mainly starch) and structural carbohydrates (a major constituent of fibre). Foods derived from grains such as oats, barley and wheat are rich in starch, which is broken down to yield glucose. Fibrous feeds are rich in the structural carbohydrates cellulose, which is broken down to yield volatile fatty acids (VFA). Both glucose and VFA are used by the donkeys to supply its body with the energy required to live (maintenance), grow, work, lactate and reproduce. If energy intake exceeds the

energy requirements the surplus is stored as fat. As well as carbohydrates the donkey can use dietary fats and proteins as a source of energy.

It is important to know the energy requirements of donkeys in order to avoid under- or over-feeding. Typically, donkeys in tropical countries are underfed and have body conditions scores of less than 4. In temperate regions donkeys are generally overfed (condition score more than 6). The consequences of both acute and chronic overfeeding in donkeys are very serious and can end in death. Management of weight loss in overweight donkeys is particularly problematic, because rapid loss in condition is likely to trigger hyperlipaemia, a disease that is usually fatal. Prevention of obesity is better than cure.

Recent research funded and carried out by the Donkey Sanctuary has established scientifically validated guidelines for donkeys kept in temperate and in tropical climates. Mature donkeys that are kept at maintenance levels (neither gaining or losing weight) require between 80 – 95 KJ of digestible energy (DE) per kilogram of live weight per day (See table 1, figure 1 - 2 for practical examples). The upper value will apply during the winter months of December – February when the energy requirement of donkeys tends to slightly increase. The lower value will apply during the height of summer.

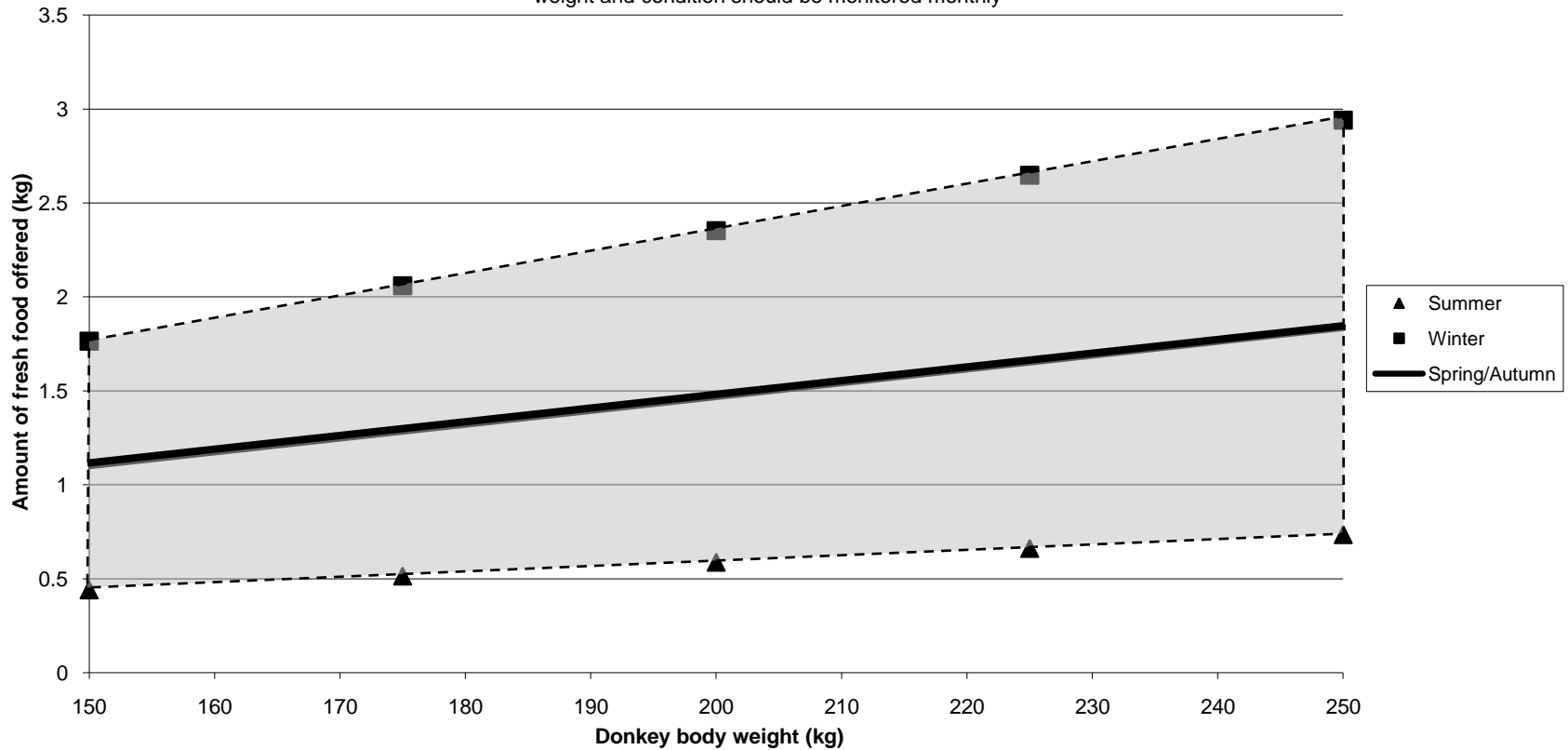
Table 1: Digestible energy requirements, dry matter intake and required energy density of the diet in donkeys of different body weights

Donkey live weight (kg)	Daily requirement for digestible energy (MJ per day)	Daily dry matter intake (kg per day)*	Required energy density of the diet (MJ per kg DM of food)
150	12 – 14	2.3	5.5 – 6.5
175	14 – 17	2.6	5.5 – 6.5
200	16 – 19	3	5.5 – 6.5
225	18 – 22	3.4	5.5 – 6.5
250	20 – 24	3.8	5.5 – 6.5

*Assuming daily dry matter intake of 1.5 % of live weight

Figure 1: Daily maintenance requirement of stabled donkeys for fresh hay (medium quality, 7 MJ DE per kg DM, 85% DM) during winter, spring, summer and autumn (as fed basis) .

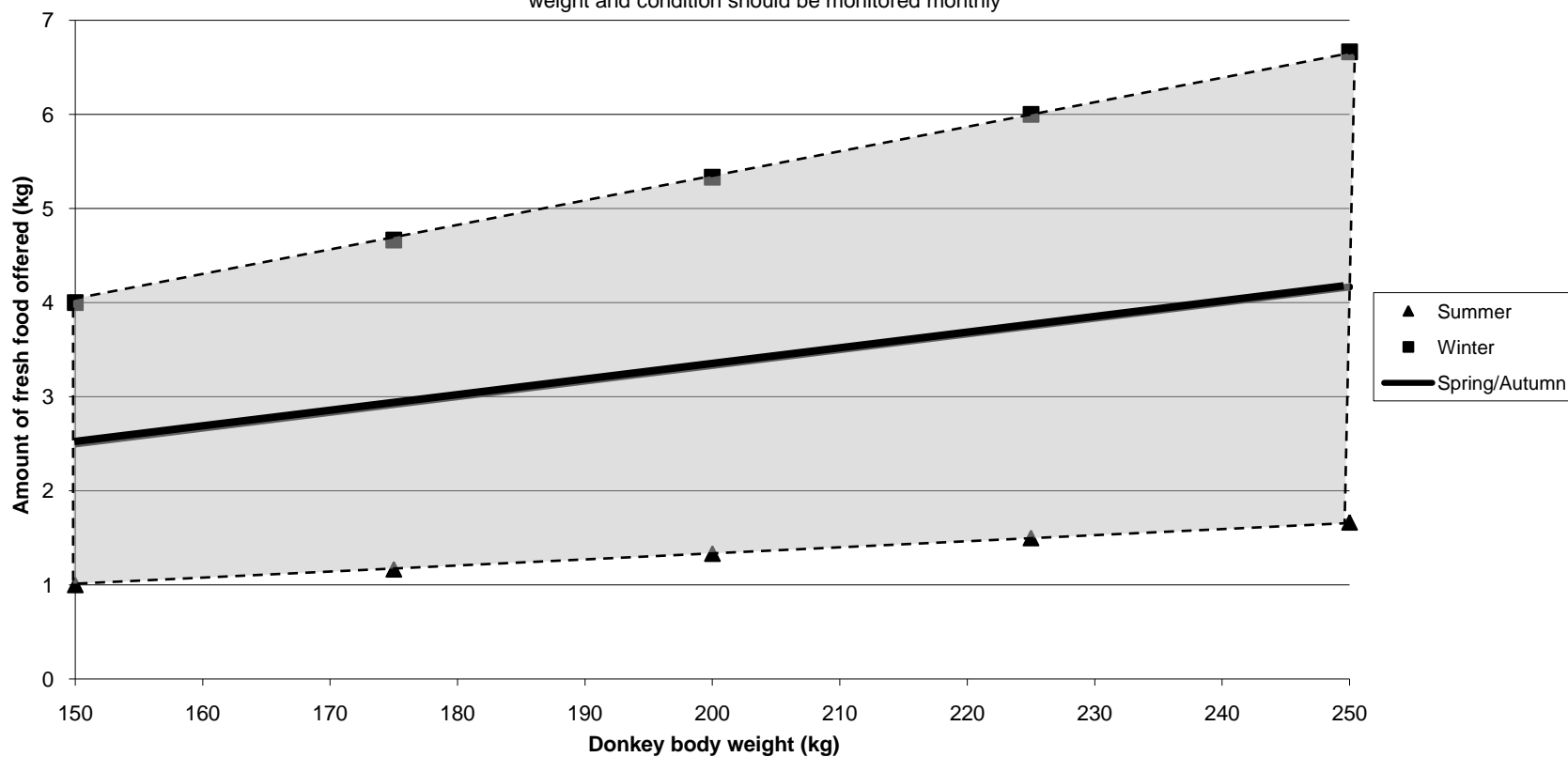
In addition free access to good quality straw, a mineral lick and a small quantity of green fodder (0.25 kg)* should be provided. Body weight and condition should be monitored monthly



*Or a vitamin supplement

Figure 2: Daily maintenance requirement of stabled donkeys for fresh haylage (medium quality, 6.5 MJ DE per kg DM, 50% DM) during winter, spring, summer and autumn (as fed basis) .

In addition free access to good quality straw, a mineral lick and a small quantity of green fodder (0.25 kg)* should be provided. Body weight and condition should be monitored monthly



*Or a vitamin supplement

In order to formulate an appropriate ration for donkeys it is necessary to estimate how much dry matter a donkey will eat per day. In the recent study at The Donkey Sanctuary, dry matter intakes of between 1.3 – 1.7% of live weight were measured in donkeys fed on straw and hay (straw was available *ad libitum*). Other published studies have reported dry matter intake values in donkeys of between 0.9 and 2.5% that were given a variety of feeds; the higher values in this range were recorded in donkeys fed on chopped lucerne. A reasonable assumption of the appetite limits of a typical donkey is therefore approximately 1.5% of its live weight in dry forage per day (i.e. a 100 kg donkey can consume 1.5 kg of dry food per day).

It is important to satisfy the energy requirement of donkeys, their appetite and their psychological need to spend large parts of the day foraging. For most of the year a ration that contains 70 - 75% barley straw and 25 - 30% of moderate quality hay will supply all the energy requirements of donkeys. During the winter when energy requirements increase the proportion of hay needs to be increased to 50 – 75% and the proportion of straw fed decreased to 25 - 50%. In practice, donkeys select hay in preference to straw, therefore simply by limiting the amount of hay fed to the required levels and offering straw *ad libitum* animals are unlikely to exceed their energy requirements. A mineral supplement will also be required and some source of vitamins either in the form of a small quantity of fresh green fodder (200g of chopped alfalfa or 500g of freshly cut pasture) or a commercial vitamin mix. A careful eye should be kept on the quality of fodders being fed; the digestible energy value can vary considerably between bales and consignments. Always check that fodder is of medium to good quality (more than 7 MJ DE per kg DM) before feeding. Fodders that are mouldy or excessively stemmy are unlikely to provide the donkey with all its energy requirements and should not be fed.

All these recommendations should be backed up by regular body condition scoring of donkeys. Using these guidelines it is apparent that donkeys kept at maintenance (the vast majority of donkeys) and fed medium quality hay, have no requirement for supplementary hard (concentrate) feed, even during winter.

When donkeys are growing, pregnant or lactating extra energy needs to be fed. Research in this area has still to be conducted but general guidelines are provided below.

Ideally immature growing donkeys should be provided with sufficient energy to allow them to grow at a steady rate avoiding periods of rapid growth acceleration or retardation. Providing too much energy to a growing donkey, especially when not balanced with adequate protein, calcium and phosphorus may result in the development of orthopaedic problems. The available time for young donkeys to attain their full mature stature is approximately 2 –3 years. Growing donkeys may face problems at weaning and during their first winter and some supplementation with concentrate feed may be required in order to avoid prolonged growth checks or permanent stunting. Pasture fed immature donkeys are unlikely to require energy supplements, but should be given access to mineral licks.

Working donkeys that are born and reared in tropical countries tend to be smaller in mature stature than non-working donkeys in temperate regions. One possible explanation for this is that poor nutrition and high parasite burdens during its early life stunts its growth. Another possibility is the early closure of bone growth plates due to premature exposure to the stresses and strains of work. An alternative view

is that the tropical breeds of donkeys are inherently smaller than those of temperature regions and their small stature is not a result of malnutrition.

In pregnant donkeys the demands of the growing foetus only exceed the normal requirements in the final three months of pregnancy. Digestible energy allowances should be increased by 11% above maintenance in the 9th month, 13% in the penultimate month and 20% in the final month of pregnancy.

Lactating jennies are likely to lose weight (1/1½ body condition score points) during the first two months that they are suckling their foals, even when they are receiving moderate feed supplementation. Preparation for this loss should be made in the final months of pregnancy by allowing pregnant jennies of body condition score 5 to gain 1 to 1½ points of body condition by additional feeding (i.e. at foaling they should have a body condition of 6). The jenny should receive sufficient additional feeding during the first 2 - 3 months of lactation to minimise body weight losses aiming to stable body condition score of 5 for the remainder of the pre-weaning period.

Protein requirements

Proteins are required by all living tissue to grow and repair body tissues. They are polypeptide chains consisting of individual amino acids linked together. The properties of individual proteins are determined from the combination and number of different amino acids comprising the polypeptide chain. Ten amino acids cannot be synthesised to any great degree by the body and must be supplied in food, these are referred to as the essential amino acids (EAA). Proteins that contain a relatively high proportion of EAA are called high quality proteins; low quality proteins contain only small amounts of EAA. The requirement for certain EAA (lysine, cystine and methionine) are much greater than others, and if the requirement for any one of these are not met in the diet the ability of the animal to grow, recover from injury, lactate or reproduce will be severely limited even if the other EAA are fed to excess.

In ruminants, another source of EAA is derived from the digestion of microbial protein that is produced as a by-product of fibre digestion. A similar process occurs in donkeys although the microbial derived EAA cannot be digested or absorbed before they are excreted in the faeces. However, the ability of donkeys to thrive and grow on the very low protein forages found in many tropical countries does provide some anecdotal evidence that processes of protein digestion and metabolism in donkeys are more complex than is currently perceived.

As a general rule, once the energy requirements of an animal are satisfied by the diet then the protein requirements tend also to be satisfied. This has been confirmed by recent studies at the Donkey Sanctuary which have measured the digestible crude protein (DCP) requirements for adult donkeys at 26 ± 1.3 g DCP per 100 kg Bwt per day (Wood *et al*, 2005). In practice this amount of DCP would be comfortably supplied from the diet based of hay and *ad libitum* straw that was suggested in the previous energy requirement section.

Fat requirement

The foods that are commonly fed to donkeys contain only small quantities of fat. However, certain feeds are rich in fat, particularly the cake remaining after the extraction of oil from seeds such as cotton, linseed, canola and sunflower. These feeds are a very rich source of energy. In the UK, the habitual inclusion of these feeds into the diets of donkeys is likely to result in gross obesity. However, in poor countries they may represent a cost-effective way of boosting the energy intake of working donkeys. Donkeys do have a specific requirement for particular essential fatty acids such as acid linoleic and α -linolenic, but the levels of these are sufficiently high in most common forages to make deficiency very unlikely under practical conditions.

Vitamin requirements

Vitamins are a diverse group of organic nutrients that animals require small quantities of to remain in good health. They have an extremely wide role in the body, some are antioxidants, others are co-enzymes or hormones. There are basically two types of vitamin, fat-soluble vitamins and water-soluble vitamins. Fat-soluble vitamins (Vitamin A, D, E and K) can be stored by the body and deficiency symptoms tend to develop slowly after a long period of deprivation. When fat-soluble vitamins are over-supplied over a very long periods of time there is a risk of toxicity developing. Water-soluble vitamins (vitamins B1, B6 and B12) cannot be stored by the body and deficiencies develop rapidly. Vitamins are very abundant in green forage; pasture fed donkeys or those fed fresh forage are highly unlikely to suffer from vitamin deficiency. Young or geriatric animals may be vulnerable to vitamin deficiency particularly when intake of green forage is restricted.

The levels of vitamins of conserved forage and cereal concentrates are generally quite low and diminish as storage time increases. Animals that are fed conserved forages and concentrates are most at risk from vitamin deficiency, particularly toward the end of the winter when the vitamin levels in food are lowest. Allowing donkeys some time to graze during the winter is very beneficial for their vitamin intake. Vitamin allowances for donkeys are shown in Table 2.

Table 2: Vitamin dietary allowances for donkeys (adapted from McDonald, Edwards, Greenhalgh and Morgan 2002)

Required vitamin level per kg DM of food	Maintenance	Pregnant and lactating jennies	Growing donkeys	Working donkeys
Vitamin A (iu /kg DM)	2000	3000	2000	2000
Vitamin D (iu /kg DM)	300	600	800	300
Vitamin E (iu /kg DM)	50	80	80	80
Thiamin (mg /kg DM)	3	3	3	5
Riboflavin (mg /kg DM)	2	2	2	2

In certain circumstances an acute vitamin deficiency can arise. Bracken contains an enzyme called thiaminase that destroys vitamin B1. Donkeys that have eaten bracken may exhibit acute neurological symptoms (circling movements, head pressing, blindness and muscular tremors) due to acute vitamin B1 deficiency. Thiaminase is also present in raw fish, so fishmeal should always be cooked before it is fed to donkeys.

The best way to provide donkeys with sufficient vitamins is to give them access to fresh green forage; even a small quantity will help stave off deficiency. If supplements are fed they should be provided in a form that does not provide additional energy to the donkey. Proprietary vitamin and mineral mixes are relatively expensive on a cost per kilogram basis but are required only in small quantities so are more cost effective than they initially appear.

Minerals

Minerals are a range of inorganic nutrients that play a wide role in the donkey's body. They are classified into two groups:

1. Macro (or major) minerals that are required in relatively large quantities (several grams per day) include the elements calcium, phosphorus, sodium, chlorine and potassium and magnesium.
2. Trace (or minor) minerals are required in relatively small amounts (milligrams per day) and include the elements copper, iron, zinc, selenium, and iodine.

Dietary requirements for several major minerals and trace elements are shown in Table 3.

Calcium and phosphorus are major constituents of bone, and they both also have a major metabolic role. Bones act as a reservoir of calcium and phosphorus, when dietary levels of the elements are low. If these deficiencies are prolonged the bones can become weakened. In young donkeys lack of calcium and phosphorus can result in developmental orthopaedic disease resulting in permanent bone deformity and weakness. Excessive dietary phosphorus can interfere with the absorption of calcium. Levels of phosphorus relative to calcium are particularly high in some by-products such as bran and cotton seed that are commonly fed to working donkeys in developing countries. Keepers should attempt to provide mineral licks wherever possible to prevent imbalance and deficiencies in calcium and phosphorus.

Sodium and chloride are lost in sweat to a greater extent than other minerals. Consequently, demands for sodium chloride are higher in working donkeys in hot environments. Care should be taken to offer working animals salt to allow them to make up for these perspiration losses. It is better to supply salt licks separately to other food, because high salt content in food tends to suppress appetite resulting in a reduction of overall nutrient intake.

Table 3: Mineral dietary allowances for donkeys (Adapted from McDonald, Edwards, Greenhalgh and Morgan 2002)

Mineral	Maintenance	Pregnant jennies	Lactating Jennies	Growing donkeys	Working donkeys
Major minerals (g/kg DM)					
Calcium	3.0	4.7	7.4	3.8	4.0
Phosphorus	2.1	3.6	4.8	2.8	2.1
Magnesium	1.1	1.1	1.4	1.5	0.5
Potassium	3.3	3.8	6.1	1.6	4.9
Sodium	1.0	1.0	1.0	1.0	3.0
Trace elements (mg/kg DM)					
Iron	40	50		50	40
Manganese	40	40		40	40
Copper	10	10		10	10
Zinc	40	40		40	40
Selenium	0.1	0.1		0.1	0.1
Iodine	0.3	0.3		0.3	0.3
Cobalt	0.1	0.1		0.1	0.1

Body condition score

When feeding donkeys its important not to forget that animals are individuals and their responses to scientifically formulated rations are not entirely predictable. An active or more excitable donkey may need more food than a more sedentary or phlegmatic field-mate. To fine-tune diets to the donkey's individual requirements body condition scoring is a useful tool.

The Donkey Sanctuary has developed a system, which uses a five-point scale to body condition score. Body condition score systems rely on the operator developing a practiced eye and hand to detect small changes in the subcutaneous fat covering. It is also important for the operator to maintain objectivity when carrying out scoring to avoid the temptation to over or under score to get a more personally acceptable result. It may be better to ask a friend or member of the family to carry out the scoring if you are having trouble maintaining objectivity. Regular monitoring of body condition is also important and should be carried out monthly, particularly in early summer when there is abundant pasture and in winter when extra fat may be used to maintain body temperature.

The tendency of horse owners to keep their horses in 'show' condition is also prevalent among donkey owners. A donkey in 'show' condition is likely to have a body condition score of at least 7 (less fat); for these animals further increases in body condition score may result life threatening obesity.

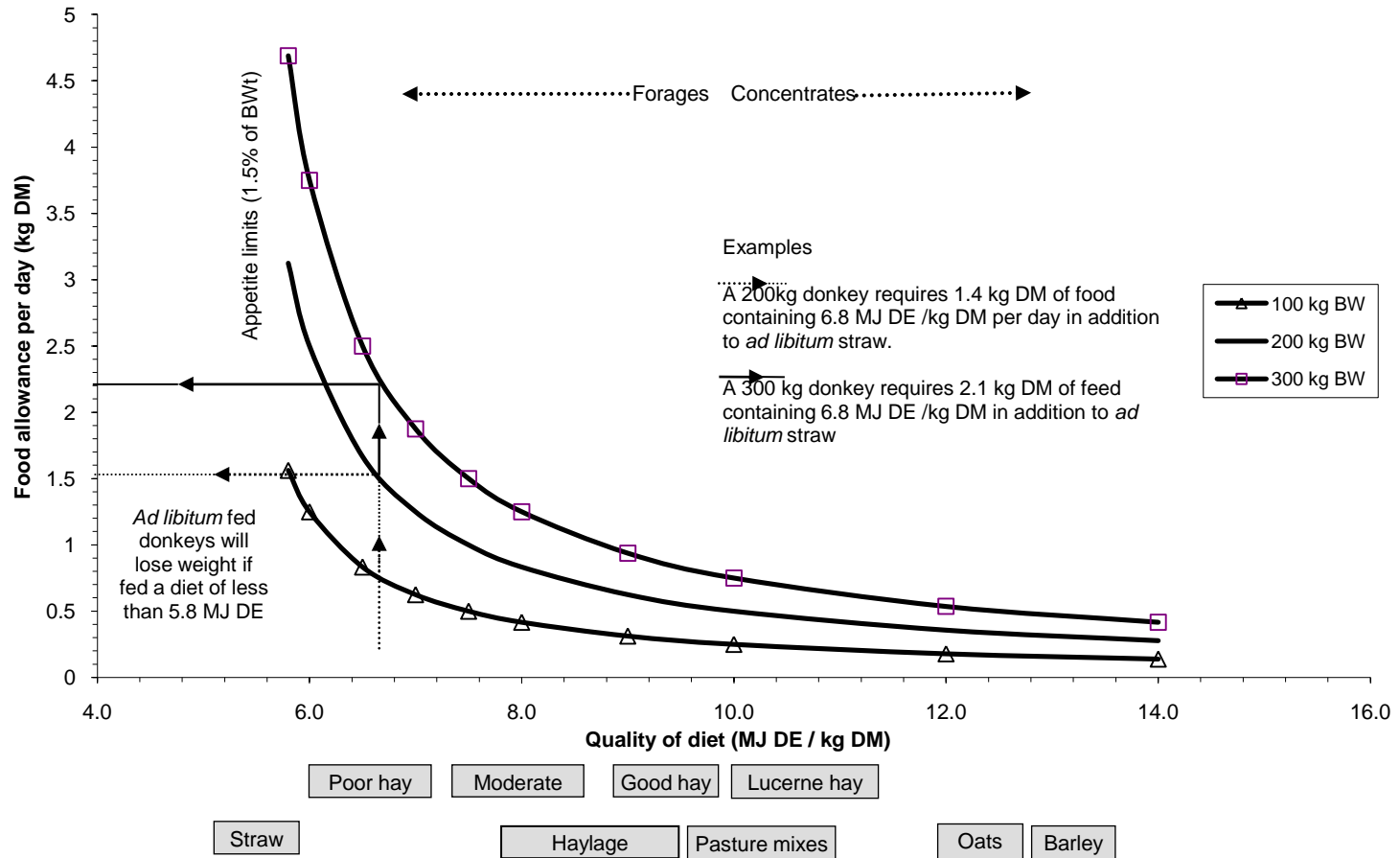
Donkeys and keepers should be calm and relaxed when body condition scoring. If the donkey is accustomed to being handled it is more likely to cooperate. The condition scoring should be carried out in an area where there is plenty of light and plenty of space to move around the donkey. Initially, place the donkey in one of the three fat classes (thin, moderate or fat) then look for specific indicators for a more precise condition score (see Appendix 4). It is important to manually and visually determine the fat covering over the neck, shoulders, back, ribs, flanks and rump taking into account the individual nature of the donkey. When you are a beginner at body condition scoring try and get a second opinion from a more experienced person.

One of the main roles that body condition scoring can play is to provide an early indication of under or over nutrition in donkeys. Once spotted these small errors can be corrected by moderate changes in the diet; if they go unnoticed over long periods more drastic action may be required.

Practical rationing

Donkeys on a maintenance diet require little more than a limited amount of moderate hay, free access to good clean straw to fill them up, a mineral/vitamin balancer and plenty of clean water. Keepers should avoid over-complicating a donkey's diet by the addition of various mixes to rectify apparent dietary problem. Most feed supplements are energy rich and even small quantities will exceed the energy requirements of the donkey (Figure 3).

Figure 3: Daily food allowances for mature donkeys at maintenance between 100kg and 300kg body weight (BWt) in addition to *ad libitum* access to good quality straw and a mineral lick. Dry matter (DM) basis.



Conclusions

- The food requirements of donkeys are generally lower than those of a similar sized pony, due to the donkey's superior ability to digest food.
- Donkeys fed to maintenance (neither gaining or losing weight) require limited amounts of hay and free access to straw.
- For stabled donkeys a diet of 25% hay and 75% straw should be adequate in the spring and autumn. The level of hay should be slightly decreased in the summer and increased to 75% in midwinter.
- Body condition scoring should be used to fine-tune a donkey's diet.
- Pasture fed donkeys require no supplementary hay, especially if they are given free access to straw.
- Mineral licks and a plentiful supply of clean water should always be provided.
- Provide an energy-free vitamin supplement during the winter, especially if the donkey has no access to fresh grazing at this time.

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