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Digestibility and gastro-intestinal transit time of diets containing different proportions of alfalfa and oat straw given to Thoroughbreds, Shetland ponies, Highland ponies and donkeys

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Abstract

A series of 4 × 4 Latin-square digestibility trials was carried out to determine whether there were any differences between different types of equid in their ability to digest diets containing different levels of fibre and protein. The equids (Thoroughbreds, Highland ponies, Shetland ponies and donkeys) were offered one of four molassed diets in turn and these contained different proportions of alfalfa and oat straw: 1·0 : 0, 0·67 : 0·33, 0·33 : 0·67, 0 : 1, respectively. The apparent digestibility of dry matter (DM), organic matter (OM), gross energy (GE), crude protein (CP), acid-detergent fibre (ADF) and neutral-detergent fibre (NDF) were estimated. The rate of passage of the different diets was measured using Cr-mordanted fibre (Cr-fibre) and Co-ethylene diamine tetra acetic acid.

All animals digested the components of the high-fibre diets less well than those of the low-fibre diets ($P < 0{\cdot}001$ *for DM, OM, GE, CP and ADF). Donkeys digested fibre more effectively than the other equids* ($P < 0{\cdot}01$ *for ADF and NDF). The gastro-intestinal transit time of the high fibre diets was significantly less than that for the low fibre diets* ($P < 0{\cdot}001$) *and donkeys retained food residues longer than the other equids* ($P < 0{\cdot}01$).

Keywords: *dietary protein, digestibility, equidae, fibre, transit time.*

Introduction

Equids, as well as other herbivores that are hind gut fermenters, are considered to be less efficient than ruminants in utilizing plant cell-wall constituents (Hintz, Schryver and Stevens, 1978). Two groups of workers (Olsson and Ruudvere, 1955; Loewe and Meyer, 1974) have illustrated the effect that fibre content of the diet can have on the relative digestibilities of foodstuffs by ruminants and equids. They showed that whilst horses and cattle were equally effective in digesting low fibre foods, cattle were better able to digest high fibre foods. They found that generally, as the fibre content of the diet increased, the digestibility of organic matter (OM) was less for both horses and cattle, but the reduction for horses was greater. In more recent studies in which OM digestibilities of 53 foods were compared in sheep and horses (Smolders, Steg and Hindle, 1990) similar conclusions were reached.

Slade and Hintz (1969) compared the digestion of alfalfa (252 g crude fibre (CF) per kg dry matter (DM)) with that of alfalfa/grain diets (178 g CF per kg DM) in non-ruminant herbivores. They found no significant difference between horses (Thoroughbred and Quarter horse mares) and ponies (Shetland mares); digestibility coefficients for the proximate constituents measured in the ponies were higher. This difference was consistent with both diets although the magnitude of the difference was slightly less on the low fibre diet. Similarly, Barth, Williams and Brown (1977) found higher digestibilities of DM and gross energy (GE) in Shetland ponies given alfalfa/orchardgrass hay (348 g CF per kg DM) than those reported for either alfalfa or orchardgrass given to light horses (e.g. Fonnesbeck, 1969; Van der Noot and Gilbreath, 1970). They suggested that ponies may be more efficient at digesting roughages compared with horses. Hintz (1990), however, following an extensive review of the literature, concluded that although the average digestibility of DM and energy was higher in ponies than in horses, the difference was small enough to justify using ponies in digestion studies to evalute foodstuffs for horses.

Úden and Van Soest (1982) confirmed that ruminants were superior to equids in digesting timothy hay fibre but reported that there was large individual variation between equids in terms of their ability to digest fibre. Ponies (mean live weight 132 kg) were more efficient at digesting DM and the cell wall components cellulose and hemicellulose compared with horses (mean live weight 388 kg). The largest horse (500 kg) had the lowest cell-wall digestibility (0·30) whilst the smallest pony (90 kg) had the highest (0·44). Feeding levels were regulated to provide sufficient digestible energy (DE) for maintenance purposes based on metabolic body size; the ponies consumed 20·7 g timothy hay per kg live weight (70·2 g $M^{0.75}$) compared to the horses, which only consumed 16·1 g/kg live weight (71·5 g $M^{0.75}$). Janis (1976) has proposed that the foraging strategy of equids is to have a voluntary food intake that is usually greater than that of ruminants. However, by way of compensation, the digestibility of food nutrients is usually higher in ruminants than in horses. From this it might be expected that higher intakes in the ponies would be associated with lower digestibilities since retention times would probably be reduced.

Recent work (Pearson and Merritt, 1991) compared the digestion of hay and barley straw by ponies and donkeys and showed that the donkeys ate less, had slower rates of passage and digested the food components more effectively than the ponies.

The current study was designed to discover any differences between horses, different types of pony and donkeys in their ability to digest fibrous diets. A brief, preliminary report of part of this study has been published (Pearson, Cuddeford, Archibald and Muirhead, 1992).

Material and methods

Animals and management

Four adult Highland pony geldings (mean weight 505 kg), four adult donkey geldings (mean weight 174 kg), and four young (1 to 2 year old) Shetland ponies, one gelding and three stallions (mean weight 108 kg), were housed in pairs in climate rooms (one pony with one donkey or two ponies together). The rooms were maintained at a temperature of approximately 13°C. The animals were tethered at each side of the climate room and separated by a central partition so that the faeces from each animal could be identified easily and collected. Four adult Thoroughbred geldings (mean weight 548 kg) were housed in individual stalls next to each other. Urine was allowed to drain down channels in the floor away from the area where faeces were voided in both the rooms and the stalls. Clean drinking water was always available from individual metered supplies and artificial light provided a constant daylength of 12 h. Each animal was walked in hand or on a horse-walker at 1·7 m/s for 2 h/day.

Diets

Four diets containing different proportions of precision-chopped, molassed oat straw and dehydrated alfalfa were prepared. The proportions of oat straw and alfalfa in each diet were 0 : 1, 0·33 : 0·67, 0·67 : 0·33 and 1 : 0, respectively. The composition of each diet is given in Table 1. The four diets were given to each of the four equid types according to a 4 × 4 Latin-square design. Each animal received each of the four diets in turn over four 21-day periods. In each of the four time periods in the experiment, one donkey, one Thoroughbred, one Shetland and one Highland pony received each diet.

Each day individual animals were offered a food calculated to provide sufficient energy to meet their maintenance energy requirements according to the formula DE (MJ/day) = 4·12 (0·975 + 0·021 M), where DE is digestible energy and M is the live weight (kg) of the animal (Pagan and Hintz, 1986). The digestibility of the GE of the oat straw and alfalfa were assumed *a priori* and thus the basis for

Table 1 *Mean (± s.e.; no. = 10) composition of the diets offered (values are g/kg dry matter (DM) unless otherwise stated)*

	Alfalfa proportion							
	1		0·67		0·33		0	
Oat straw proportion	0		0·33		0·67		1	
	Mean	s.e.	Mean	s.e.	Mean	s.e.	Mean	s.e.
Dry matter (g/kg)	865	3·2	844	4·2	815	4·8	764	10·4
Organic matter	907	1·4	908	1·7	908	2·1	914	2·2
Neutral-detergent fibre	401	6·5	459	13·5	523	12·0	621	15·8
Acid-detergent fibre	317	6·8	328	9·7	365	7·6	389	12·0
Crude protein	171	4·3	138	3·4	100	4·1	48	2·0
Gross energy (MJ/kg DM)	18·01	0·10	18·07	0·09	17·80	0·09	17·19	0·14

rationing the groups of animals was the same. The daily ration was divided into four equal meals and given at 08.00 h, 12.00 h, 16.00 h and 20.00 h, in deep-sided troughs in order to reduce spillage. Any food refusals were collected at 08.00 h each day before fresh food was offered.

Measurements and rate of passage markers

Each animal was weighed at the start of the experiment and twice weekly to the end of the experimental period. For the first 14 days of each period the animals were allowed to adapt to the new diet. During the final 7 days, measurements of food intake and total faecal collections were made. Mean retention time (MRT) of two indigestible food markers (Cr-mordanted hay fibre, a solid phase marker and Co-ethylene diamine tetra acetic acid (EDTA), a liquid phase marker) were measured using the techniques described by Pearson and Merritt (1991).

Complete faecal collections were made at regular intervals from 23.00 h on day 14 (administration of markers) for 7 days until the end of the period. For estimation of MRT, faeces from each animal collected at 9, 11, 13, 15, 17, 20, 23, 31, 33, 35, 37, 39, 41, 46, 57, 61, 65, 70, 81, 85, 89, 94, 105, 113, 129, 137, 153, 161 and 177 h after marker administration. Individual faecal collections were weighed, thoroughly mixed and a subsample taken for determination of DM and marker concentrations. A further sample (proportionately 0·02 by weight) from each collection was pooled over the 7-day period for each animal for subsequent fibre, energy and nitrogen analysis. All samples were dried in a forced draught-oven at 60°C to constant weight and then ground through a 1 mm screen before analysis. Acid-detergent fibre (ADF), neutral-detergent fibre (NDF), crude protein (CP), GE and OM were determined according to the methods of the Association of Official Analytical Chemists (1990).

Calculations and statistical analyses

Apparent digestibilities were calculated from total DM intakes and faecal DM outputs over the 7-day collection periods. The MRTs of Cr-fibre and Co-EDTA were calculated as described by Pearson and Merritt (1991).

The design of the experiment was a standard change-over design comprising four Latin squares, one for each type of equid. The data obtained were subjected to an analysis of variance using GENSTAT (Lawes Agricultural Trust, 1990). In the analysis, the total sum of squares was partitioned into three strata representing variation between animals, variation between periods, and animal × period interaction. Overall equid effects were estimated and tested from the between-animal stratum (d.f. = 12). Diet effects and equid × diet interaction were estimated and tested from the animal × period stratum (d.f. = 33). Residual effects of dietary treatment were tested for carry-over using covariance analysis and were not found to be significant for any of the measurements.

Results

Temperature and relative humidity

Ambient temperatures and relative humidities were monitored in the climate rooms. The averages of the daily values achieved for each room for the 9 days at the end of each period (no. = 9) were calculated. Average daily maximum temperatures varied between 12 and 15°C between rooms, minimum temperatures recorded varied between 9 and 14°C, and average relative humidity at 10.00 h ranged between 0·60 and 0·79. There were significant differences between rooms only for minimum ambient temperature ($P < 0.05$). The minimum daily temperature was associated with washing-out (hosing) of the rooms (once daily). Temperatures returned to average values within 30 min of the completion of room washing. Variation in relative humidity within the day were large (±0·10) possibly due to changes in free-standing water.

Period effects on the experimental results

Experimental observations on each animal lasted for 12 weeks, during which time each animal received each dietary treatment for a 3-week period. The amount of experimental variation that could be accounted for by period effects was not significant.

Food and water intake

The animals were given food to meet maintenance energy requirements using the different diets. Hence the daily allowance and the actual intakes of the low energy, high fibre whole oat straw diet, expressed per kg live weight, were significantly ($P < 0.001$) higher than those of the less fibrous, more energy dense whole alfalfa diet. The intakes of the other diets were intermediate between these two values; increasing with increasing fibre content (Table 2).

Most animals consumed all of the food offered each day. The exceptions were those given just oat straw. Two of the Shetland ponies intermittently refused up to one-third of the straw allocation. The Thoroughbreds had refusals but proportionately they did not exceed 0·2 of their straw allocation. One of the Highland ponies often left up to one-quarter of the straw diet, but not on a regular basis. Refusals of the whole straw diet by two other Highland ponies proportionately did not exceed 0·1 of the allocation on any day, but again, refusals were irregular. These findings suggest that the amount of oat straw needed

Table 2 *Mean daily dry matter (DM), digestible energy (DE), digestible crude protein (DCP) and voluntary water intakes by Thoroughbreds (TB), Highland ponies (H pony), donkeys and Shetland ponies (S pony) when given diets containing different proportions of alfalfa (ALF) and oat straw (OS)*

	Diet proportions		Type of equid					Significance of effects	
	ALF	OS	TB	H pony	Donkey	S pony	Mean		
Daily intake of:									
DM (g/kg M)	1	0	10·4	9·6	11·2	12·4	10·9	Type	*
	0·67	0·33	11·5	10·5	12·4	14·1	12·1	Diet	***
	0·33	0·67	13·1	12·3	14·3	15·0	13·7	Type × diet	
	0	1	13·7	12·1	15·3	15·5	14·2		
	Mean		12·2	11·1	13·3	14·3			
		s.e.d.† = 1·11	s.e.d.‡ = 0·85		s.e.d.‖ = 0·81		s.e.d.§ = 0·44		
DM (g/kg $M^{0.75}$)	1	0	49·7	45·0	40·2	39·9	43·7	Type	**
	0·67	0·33	55·2	49·5	44·7	45·2	48·7	Diet	***
	0·33	0·67	63·0	58·3	51·7	48·2	55·3	Type × diet	
	0	1	65·9	57·5	56·1	49·0	57·1		
	Mean		58·5	52·3	48·2	45·6			
		s.e.d.† = 3·78	s.e.d.‡ = 3·36		s.e.d.‖ = 2·41		s.e.d.§ = 1·68		
DE (kJ/kg M)	1	0	120	113	132	128	123	Type	**
	0·67	0·33	117	105	132	123	119	Diet	**
	0·33	0·67	122	116	142	140	130	Type × diet	
	0	1	101	98	123	125	112		
	Mean		115	108	132	129			
		s.e.d.† = 9·7	s.e.d.‡ = 8·4		s.e.d.‖ = 6·39		s.e.d.§ = 4·2		
DCP (g/kg M)	1	0	1·41	1·36	1·36	1·09	1·31	Type	***
	0·67	0·33	1·01	0·96	0·99	0·74	0·92	Diet	***
	0·33	0·67	0·57	0·61	0·60	0·60	0·59	Type × diet	**
	0	1	0·05	0·05	0·05	0·04	0·05		
	Mean		0·76	0·74	0·74	0·63			
		s.e.d.† = 0·035	s.e.d.‡ = 0·031		s.e.d.‖ = 0·023		s.e.d.§ = 0·015		
Water (l/kg DM)	1	0	3·94	3·71	1·19	2·21	2·76	Type	**
	0·67	0·33	3·91	4·72	1·95	2·51	3·27	Diet	
	0·33	0·67	3·84	4·12	2·00	2·51	3·12	Type × diet	
	0	1	3·78	4·34	2·59	2·36	3·27		
	Mean		3·87	4·22	1·93	2·40			
		s.e.d.† = 0·669	s.e.d.‡ = 0·477		s.e.d.‖ = 0·526		s.e.d.§ = 0·238		

† s.e.d. for comparison between two means for different types of equid.
‡ s.e.d. for comparison between two means for the same type of equid.
§ s.e.d. for comparison between overall means for equid types.
‖ s.e.d. for comparison between overall means for diet types.

to meet maintenance energy requirements was near to voluntary, *ad libitum* intake for some of the animals. The data in Table 2 include those animals that had refusals when given straw. When intakes of the different diets were compared between the different equid types on the basis of daily DM intake per kg $M^{0.75}$ they were significantly higher in the Thoroughbreds and lower in the Shetland ponies than in the donkeys and Highland ponies ($P < 0{\cdot}01$). When expressed per kg live weight, the differences in intake between the different equids were just significant ($P < 0{\cdot}05$, Table 2). The Shetland ponies had the highest DM intakes per kg live weight, followed by the donkeys, the Thoroughbreds and then the Highland ponies.

Water intake was not significantly different on any of the different diets when expressed per unit of DM consumed, but did differ significantly ($P < 0{\cdot}01$) between the different types of equid. The donkeys had the lowest water intakes, followed by the Shetlands. Both these equids had significantly lower water intakes than the Thoroughbreds and the Highland ponies ($P < 0{\cdot}01$; Table 2).

Live weight

Animals had significantly ($P < 0·05$) greater live weights when given the two diets containing the most straw (0·67 : 0·33 and 1 : 0, oat straw : alfalfa); these diets were associated with the highest intakes and therefore greatest gut-fill.

Apparent digestibility coefficients

There was a wide range of values measured for the apparent digestibility coefficients of the food nutrients (Table 3) caused by the different diets. Diet had a significant effect on the apparent digestibility coefficients for DM, OM, GE, CP and ADF

Table 3 *Mean apparent digestibility of dry matter (DM), organic matter (OM), gross energy (GE), crude protein (CP), acid detergent fibre (ADF) and neutral detergent fibre (NDF) in Thoroughbreds (TB), Highland ponies (H pony), donkeys and Shetland ponies (S pony) given diets containing different proportions of alfalfa (ALF) and oat straw (OS)*

	Diet proportions		Type of equid					Significance of effects
	ALF	OS	TB	H pony	Donkey	S pony	Mean	
Apparent digestibility coefficients								
DM	1	0	0·69	0·68	0·67	0·59	0·66	Type **
	0·67	0·33	0·61	0·58	0·62	0·52	0·58	Diet ***
	0·33	0·67	0·56	0·55	0·56	0·54	0·55	Type × diet
	0	1	0·48	0·50	0·48	0·46	0·48	
	Mean		0·58	0·58	0·58	0·53		
	s.e.d.† = 0·022	s.e.d.‡ = 0·020			s.e.d.‖ = 0·013		s.e.d.§ = 0·010	
OM	1	0	0·68	0·69	0·70	0·62	0·67	Type ***
	0·67	0·33	0·60	0·59	0·64	0·52	0·59	Diet ***
	0·33	0·67	0·55	0·56	0·59	0·55	0·56	Type × diet *
	0	1	0·48	0·51	0·52	0·51	0·50	
	Mean		0·58	0·59	0·61	0·55		
	s.e.d.† = 0·17	s.e.d.‡ = 0·018			s.e.d.‖ = 0·007		s.e.d.§ = 0·009	
GE	1	0	0·64	0·65	0·65	0·57	0·63	Type ***
	0·67	0·33	0·57	0·55	0·59	0·48	0·55	Diet ***
	0·33	0·67	0·53	0·53	0·56	0·52	0·54	Type × diet *
	0	1	0·43	0·47	0·47	0·47	0·46	
	Mean		0·54	0·55	0·57	0·51		
	s.e.d.† = 0·020	s.e.d.‡ = 0·021			s.e.d.‖ = 0·008		s.e.d.§ = 0·010	
CP	1	0	0·77	0·74	0·74	0·66	0·72	Type
	0·67	0·33	0·68	0·64	0·66	0·56	0·64	Diet ***
	0·33	0·67	0·55	0·58	0·57	0·55	0·56	Type × diet
	0	1	0·10	0·10	0·10	0·08	0·09	
	Mean		0·52	0·52	0·52	0·46		
	s.e.d.† = 0·032	s.e.d.‡ = 0·027			s.e.d.‖ = 0·021		s.e.d.§ = 0·013	
ADF	1	0	0·47	0·49	0·50	0·42	0·47	Type **
	0·67	0·33	0·39	0·40	0·46	0·31	0·39	Diet ***
	0·33	0·67	0·38	0·38	0·42	0·42	0·40	Type × diet
	0	1	0·37	0·42	0·44	0·44	0·41	
	Mean		0·40	0·42	0·45	0·40		
	s.e.d.† = 0·031	s.e.d.‡ = 0·031			s.e.d.‖ = 0·014		s.e.d.§ = 0·016	
NDF	1	0	0·44	0·43	0·45	0·43	0·44	Type
	0·67	0·33	0·43	0·42	0·50	0·33	0·42	Diet
	0·33	0·67	0·44	0·41	0·47	0·46	0·44	Type × diet *
	0	1	0·41	0·47	0·49	0·47	0·46	
	Mean		0·43	0·43	0·48	0·42		
	s.e.d.† = 0·033	s.e.d.‡ = 0·031			s.e.d.‖ = 0·019		s.e.d.§ = 0·015	

† s.e.d. for comparison between two means for different types of equid.
‡ s.e.d. for comparison between two means for the same type of equid.
§ s.e.d. for comparison between overall means for equid types.
‖ s.e.d. for comparison between overall means for diet types.

($P < 0{\cdot}001$). These digestibility coefficients decreased as more straw was included in the diet. The differences in the apparent digestibility of fibre between diets were not so marked as for the other nutrients. The greatest difference in ADF apparent digestibility was seen between the whole alfalfa diet (0·47) and the other forage mixtures ($P < 0{\cdot}001$) (0·39, 0·40 and 0·41, respectively for the oat straw : alfalfa diets 0·33 : 0·67, 0·67 : 0·33 and 1 : 0). There was no consistent difference in NDF apparent digestibility between diets. The apparent digestibility coefficients for protein measured in animals given the whole oat straw diet are included for completeness, but are of little relevance in view of the very low protein content of the straw (48 g/kg DM).

There were significant differences between types of equid in terms of their ability to digest the diets (Table 3). The Shetland ponies digested the DM, OM, GE and CP of the different diets significantly less well than the other equids ($P < 0{\cdot}01$). The effect was more noticeable when they were given the more digestible alfalfa diet (mean DM apparent digestibility coefficient 0·66) than when given the oat straw diet (mean DM apparent digestibility coefficient 0·48). The fibre (NDF and ADF) apparent digestibility coefficients tended to vary considerably between diets and between individuals when measured in the horses and ponies, particularly when the animals were given the mixed roughage diets. In fact, fibre apparent digestibilities for the single forages (alfalfa or oat straw) tended to be higher than those determined for the mixed forage diets.

Digestibilities of OM, GE, ADF and particularly NDF, measured in the donkeys were consistently higher than those values obtained with the horses or ponies ($P < 0{\cdot}01$).

The only significant ($P < 0{\cdot}05$) interactions between type of equid and diet occurred when the apparent digestibility of OM, GE and NDF was measured (Table 3). The Thoroughbreds appeared to digest the OM and GE in the diets with the higher levels of alfalfa better than the Shetland ponies, but the opposite effect was seen when the oat straw diet was given.

Rate of passage of digesta through the digestive tract

Average recovery rates of Cr-fibre and Co-EDTA were proportionately 0·88 and 0·93 respectively over the 7-day collection periods. Differences in recovery rates between individual animals were not related to

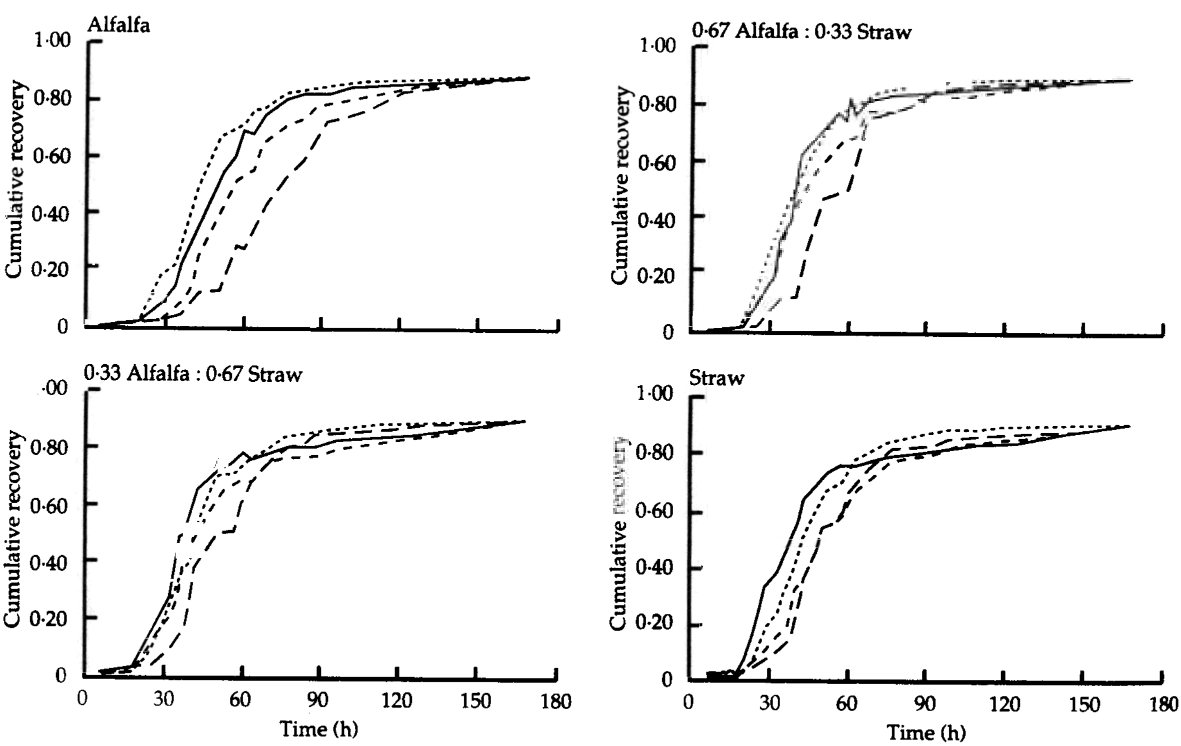

Figure 1 Mean cumulative proportional recovery rates of Cr-fibre for horses, ponies and donkeys for each dietary treatment (means of four animals): ——— horse; — — — donkey; – – – – Highland pony; · · · · · Shetland pony.

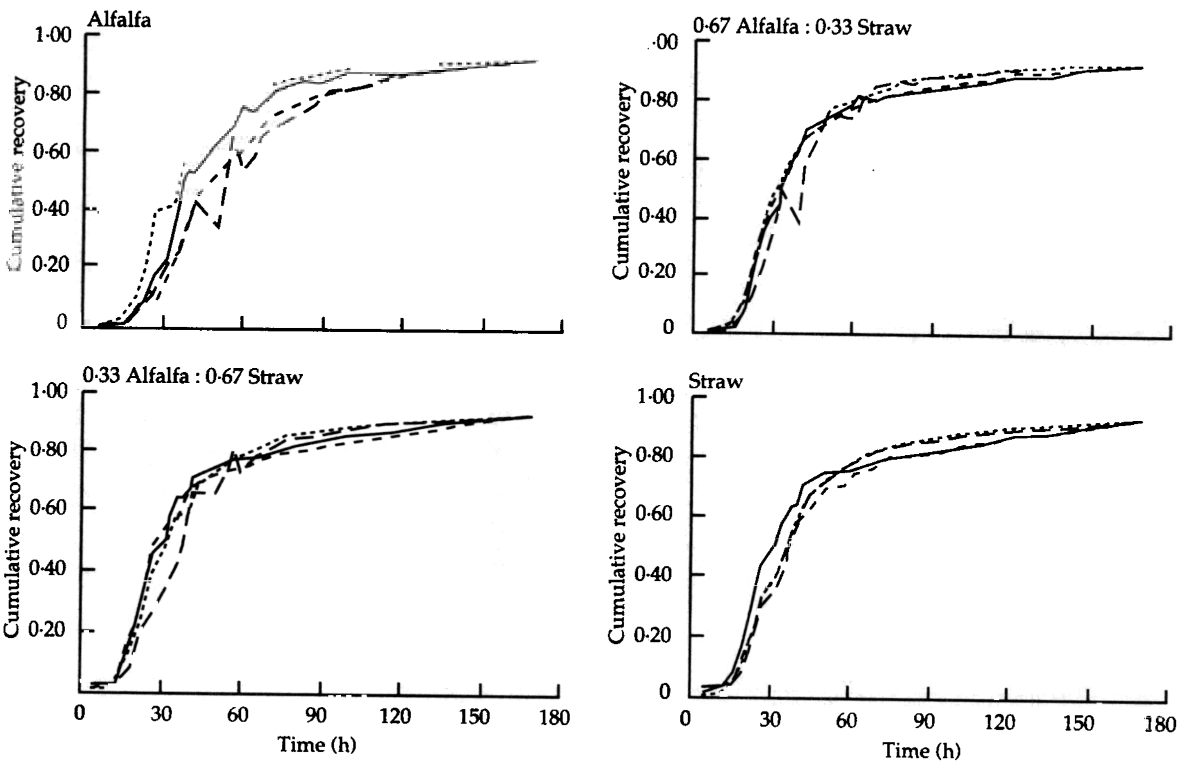

Figure 2 Mean cumulative proportional recovery rates of Co-EDTA for horses, ponies and donkeys for each dietary treatment (means of four animals): ——— horse; — — — donkey; - - - - Highland pony; · · · · · Shetland pony.

equid type. The mean cumulative recoveries of Cr-fibre and Co-EDTA by the different groups of animals and for the different diets are given respectively in Figures 1 and 2. Proportionately about 0·80 of each marker was egested within the first 75 h of the collection period. The cumulative recovery curves of Co-EDTA show less variation between equid types than those for Cr-fibre. Table 4 shows the MRTs of Cr-fibre and Co-EDTA. As might be expected, the MRT of Cr-fibre (the solid-phase marker) was longer than that of Co-EDTA (the liquid-phase marker) in most of the animals regardless of diet. The exceptions were the Thoroughbreds, which showed remarkably similar MRTs of Cr-fibre and Co-EDTA on each of the diets. Diet had a significant effect ($P < 0{\cdot}001$) on MRT of Cr-fibre and Co-EDTA. Not surprisingly, MRT was greatest with the alfalfa diet, the diet with the highest energy density and therefore given in the smallest amount during the experiment. In contrast, rate of passage of digesta through the tract increased considerably when the animals were given diets that contained straw. Differences in MRT for the three diets containing oat straw were small.

Consistently slower rates of passage of the solid-phase marker were measured for all the diets given to the donkeys compared with when given to the other equids ($P < 0{\cdot}01$). Differences in MRTs of the liquid-phase marker between equids were less noticeable, although in most cases, the donkeys had longer MRTs, matched only by the Highland ponies given some of the diets.

There was a significant interaction ($P < 0{\cdot}05$) between type of equid and diet in the MRT of Cr-fibre. The MRT of Cr-fibre in the gastro-intestinal tract of the Thoroughbreds, Highland ponies and donkeys appeared to be influenced by diet. However, in the Shetland ponies, diet seemed to have little effect on MRT of Cr-fibre (Table 4). Although no significant interaction between equid type and diet was observed for Co-EDTA, the Shetland ponies tended to have the lowest MRTs of Co-EDTA on all of the diets, compared with values obtained for the other equids.

Discussion

The smallest ponies (Shetlands) consumed more DM (g/kg M) compared with the Highland ponies and Thoroughbreds. This observation is similar to that reported by Úden and Van Soest (1982), although in the present study, the Shetland ponies were not more

Table 4 *The mean retention time (h) of Cr-fibre and Co-EDTA in the digestive tract of Thoroughbreds (TB), Highland ponies (H pony) donkeys and Shetland ponies (S pony) given diets containing different proportions of alfalfa (ALF) and oat straw (OS)*

	Diet proportions		Type of equid					Significance of effects	
	ALF	OS	TB	H pony	Donkey	S pony	Mean		
Mean retention time (h)									
Cr-fibre	1	0	51·9	63·7	76·7	46·3	59·6	Type	**
	0·67	0·33	44·1	50·4	59·2	44·2	49·5	Diet	
	0·33	0·67	42·2	51·5	55·3	46·7	49·0	Type × diet	
	0	1	38·4	51·3	53·8	46·9	47·6		
	Mean		44·2	54·2	61·2	46·0			
			s.e.d.† = 4·58	s.e.d.‡ = 3·33			s.e.d.§ = 1·67		
					s.e.d.‖ = 3·56				
Co-EDTA		0	51·1	59·4	61·8	41·6	53·5	Type	
	0·67	0·33	44·3	43·0	47·2	40·2	43·7	Diet	
	0·33	0·67	42·9	45·9	48·6	42·7	45·0	Type × diet	
	0	1	43·5	48·3	46·0	44·7	45·9		
	Mean		45·4	49·4	50·9	42·3			
			s.e.d.† = 5·14	s.e.d.‡ = 3·70			s.e.d.§ = 1·85		
					s.e.d.‖ = 4·02				

† s.e.d. for comparison between two means for different types of equid.
‡ s.e.d. for comparison between two means for the same type of equid.
§ s.e.d. for comparison between overall means for equid types.
‖ s.e.d. for comparison between overall means for diet types.

efficient at digesting food nutrients when compared with the Thoroughbred and Highland ponies. The apparent digestibility coefficients for DM, OM and GE measured in the Shetland ponies were consistently lower than those for the larger animals (Table 3). This would seem to support the hypothesis that there is a relationship between DM intake (expressed per kg M) and nutrient digestibility, since the animals with the lower intakes digested food nutrients more effectively. However, donkeys did not fit this pattern. They consumed almost as much DM (13·3 g/kg M) as the Shetland ponies (14·3 g/kg M), but they consistently digested DM, OM and GE more effectively than the other equids. This superior capability to digest fibre compared with ponies agrees with previous results obtained with both restricted (Wolter and Velandia, 1970) and *ad libitum* fed animals (Pearson and Merritt, 1991; Tisserand, Faurie and Toure, 1991; Suhartanto, Julliand, Faurie and Tisserand, 1992). This superior ability of donkeys is almost certainly due to the fact that they are able to retain food particles for longer in the digestive tract compared with the other animals. That the Shetlands consumed the most DM (g DM per kg M) is not surprising since they were rationed according to an estimate of maintenance energy requirement that was based on a linear equation that incorporated a large *Y* intercept (0·975); this intercept has an effect similar to the use of a power function of body weight. Thus, the Shetland ponies were offered more food, had the highest intake per kg body weight but on the basis of metabolic body size (M$^{0\cdot75}$ they received significantly less than the heavie animals.

Fluctuations in live weight could be explained b changes in gut-fill due to the different diets that wer offered. Animals consistently showed the heavies live weights when given diets with the highest fibr content and intake allowances (0·67 : 0·33 and 1 : (oat straw : alfalfa). The fact that those animals tha did not consume all of their food ration, but stil maintained live weight suggests that they had higher efficiency of digestion, a reduced maintenanc energy need, or possibly a greater gut-fill.

The mean apparent digestibility coefficients for OM CP and ADF of dehydrated alfalfa offered to th animals in the present study were 0·67, 0·72 and 0·47 respectively (Table 3). Previous studies in thi laboratory with dehydrated alfalfa (304 g ADF per k DM) given to Thoroughbreds showed similar OM (0·63) and CP (0·74), but lower ADF (0·35) value (Cuddeford, Woodhead and Muirhead, 1992). Th coefficients in the current study are similar to thos reported by Hintz (1969) for alfalfa hay (310 g CF pe kg DM) offered to horses, which were 0·59, 0·75 an 0·41 (CF not ADF) respectively. An alfalfa hay give to donkeys was reported (Izraely, Chosniak, Stevens Demment and Shkolnik, 1989) to have an AD digestibility of 0·47 which is similar to the valu (0·50) obtained in the present study.

The mean apparent digestibility coefficients reported here for ADF (0·41) and OM (0·50) of oat straw are different from those reported by Hintz (1969), where surprisingly the CF value was high at 0·51 and the OM value was only 0·44. This might have been accounted for by the fact that the oat straw used in the present study contained only 389 g ADF per kg DM compared with that used by Hintz (1969) which contained 400 g CF per kg DM. Digestibility values for oat straw given to donkeys have not been reported before, but coefficients for other straws are available. An ADF digestibility has been reported in *ad libitum* fed donkeys as 0·42 for wheat straw containing 484 g ADF per kg DM (Izraely *et al.*, 1989) and 0·38 for wheat straw containing 465 g ADF per kg DM (Suhartanto *et al.*, 1992). These values compare with the value of 0·44 obtained for oat straw in the present study. An ADF digestibility for barley straw (567 g ADF per kg DM) offered *ad libitum* to donkeys was determined to be 0·52 (Pearson and Merritt, 1991), with an associated OM digestibility of 0·48.

For herbivores, and equids in particular, the fibre content of a diet has been found to have a marked influence on nutrient digestibility (Fonnesbeck, Lydman, Van der Noot and Symons, 1967); the higher the fibre the lower the digestibility value. This relationship was confirmed in the present study when the Thoroughbreds, Highland ponies and donkeys were given the different diets. This relationship was less clear in the Shetland ponies, probably because of the low digestibilities measured in these animals when given the 0·67 : 0·33 (alfalfa : oat straw) diet. Generally, the level of fibre in the diet, seemed to have little effect on the animals' abilities to digest the fibrous components, although the combination of 0·67 : 0·33 alfalfa and oat straw depressed both ADF and NDF digestibilities in these animals. It is noteworthy that the other equids were not similarly affected and no explanation can be offered for this anomaly.

The present study confirmed the observation of Uden and Van Soest (1982) that there is considerable individual variation between equids in their ability to digest fibre. However, apparent digestibility coefficients for the fibrous components of the single forages were less variable than those of the mixtures. Some of the variation may be explained by the difficulty in achieving an homogenous mix of oat straw and alfalfa, subsequent problems of adequately sampling these mixed forages and possible food interactions.

The amount of energy and nitrogen available to the microflora in the hind gut will affect the ability of equids to digest fibrous, plant cell-wall components. In the current study, energy intake was not limited although there were large differences in protein intake. Variation in ADF and NDF apparent digestibilities obtained between diets and between animals may have partly reflected these differences in nitrogen availability and subsequent microbial activity. However, the lack of any marked depression in ADF and NDF apparent digestibility associated with the decrease in digestible CP intake as the dietary straw content increased (Table 3) suggests that when the dietary supply of nitrogen is low, the equid has some mechanism that sustains the nitrogen supply to the hind gut. The donkey appears to be the most successful equid in terms of digesting fibre on low protein diets and this may be because it has the best developed mechanism for nitrogen recycling to the hind gut. In support of this, Izraely *et al.* (1989) found that when donkeys were given a low protein (45 g CP per kg DM) wheat straw compared with when given high protein (360 g/kg DM) alfalfa hay, there was a decrease in the urea filtration rate. This was combined with an increase in the fractional urea resorption, which subsequently increased retention of urea nitrogen and recycling of nitrogen into the hind gut.

The situation with horses and ponies is unclear although Prior, Hintz, Low and Visek (1974) have produced evidence to show that urea is recycled to the hind gut of ponies. However, nothing is known of the controlling circumstances under which the return occurs or of the extent to which it presents a contribution to, or a penalty on, the nitrogen economy of the animal.

The low nutrient apparent digestibilities measured in the Shetland ponies, compared with those obtained in the other animals, were more noticeable as the alfalfa content of the diet increased. The measurement of digestibility, particularly of roughage diets, in very small equids (*ca.* 100 kg) may not be representative of the situation in larger horses. This may be because their small size may reduce the effectiveness of digestive processes, particularly fermentation which is affected by both the size of the reaction vessel and the out-flow rate (Hume and Sakaguchi, 1991). Hintz (1990) concluded that ponies can be used in digestion studies to evaluate foodstuffs for horses although the minimum mean weight of the ponies used in the different experiments he reviewed was 132 kg and mostly the ponies weighed 160 kg or more. The immature ponies used in the current study may have had a smaller large intestine : body weight ratio than the larger equids and could have been disadvantaged. This relative disadvantage should have been most marked on the high fibre diets (containing oat straw) but in fact the discrepancy was most obvious when the dietary alfalfa content increased and intake was reduced. A possible explanation for this apparent anomaly could be that the Shetland ponies consumed less digestible CP (g/kg DM) compared with the other animals.

Lower water intakes per kg food consumed by donkeys as compared with other equids have been reported elsewhere (e.g. Mueller and Houpt, 1991) and may reflect the donkeys' desert origins. Water intake per kg DM increased with increasing straw inclusion in the diet by up to 0·51. Although, this increase was not significant, it may reflect greater water retention in the lumen of the gut which in turn may affect the rate of passage of digesta. Hydrophilic polysaccharides, such as hemicellulose, absorb water and hold it in the lumen of the gut. This is reflected in the high water content of the faeces voided by animals given hemicellulose-rich diets (e.g. timothy hay, straw) compared with those given diets low in hemicellulose (e.g. alfalfa). Cuddeford *et al.* (1992) have shown that Thoroughbred horses given only alfalfa (130 g hemicellulose per kg DM) voided four times as much water in the urine and produced drier faeces than those given timothy hay. However, mean water intakes (l/kg DM) were similar, DM intakes were the same and although rate of passage was quicker for the alfalfa, there were no significant differences. The relationship between water intake and nutrient digestibility in the donkey is as yet untested.

It has been proposed that compared with the ruminant, the horse is better adapted to deal with fibrous foods when they are available *ad libitum* (Illius and Gordon, 1990). The adaptation is that the horse will eat more low quality roughage than the ruminant, although the digestibility of the nutrients will be less in the horse. It is not known if there are different strategies employed by members of the equidae to digest high fibre diets. For example, is there any attempt to regulate intake and rate of passage of ingesta thereby affecting exposure time to enzymatic and microbial activity? The results of the current study suggest that donkeys have a different strategy from other equids, because they have a higher intake of food and digest nutrients more effectively in contrast to horses and ponies, where high intakes are associated with lower nutrient digestibilities. Previous work (Pearson and Merritt, 1991) has shown that donkeys given straw *ad libitum* had a slower rate of passage of food residues, and higher OM digestibility compared with ponies given the same diet. It is proposed that donkeys are more efficient at digesting fibrous foods because they have a higher mean retention time of food particles in the gut regardless of intake. Where the food resource is limited, the donkey, like the ruminant, would have an advantage, but, where there are unlimited food supplies, the pony or horse can compensate for reduced digestive efficiency by consuming and processing more food.

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