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FIBRE DIGESTION AND DIGESTA RETENTION TIME IN GUINEA-PIGS (*CAVIA PORCELLUS*), DEGUS (*OCTODON DEGUS*) AND LEAF-EARED MICE (*PHYLLOTIS DARWINI*)

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Abstract—1. Digestibilities of feed and turnover time ($1/k$), Transit time (TT) and mean retention time (MRT: $1/k$ + TT) of fluid and particle markers were measured in the guinea-pig (*Cavia porcellus*), degu (*Octodon degus*) and leaf-eared mouse (*Phyllotis darwini*) fed a diet containing 50% alfalfa.

2. The digestibility of fibre and the retention time of digesta were highest in the guinea-pig followed by the degu and lowest in the leaf-eared mouse.

3. The difference in the retention time of digesta, resulting from the variation in the digestibility of fibre, between the three animals can be considered to be related to their body mass.

INTRODUCTION

The guinea-pig (*Cavia porcellus*) and degu (*Octodon degus*) which are the native rodents in South America, belong to Caviomorpha. The leaf-eared mouse (*Phyllotis darwini*) which belongs to Myomorpha is also native in South America.

The guinea-pig is a strictly herbivorous, monogastric animal with a voluminous caecum which can retain digesta for a considerable time (Sakaguchi *et al.*, 1986), and is more efficient in the digestion of fibre and its components than rabbits, hamsters and rats (Sakaguchi *et al.*, 1987). It has been reported that guinea-pigs digest organic matter and crude fibre as efficiently as horses and ponies (Slade and Hintz, 1969). The degu and leaf-eared mouse are also herbivores which have a well-developed caecum.

Digestibilities of forage fibre vary amongst different herbivores (Slade and Hintz, 1969; Paul-Murphy *et al.*, 1982; Udén and Van Soest, 1982; Sakaguchi *et al.*, 1987). The extent of fibre digestion in several small hindgut fermenters is related more closely to the turnover time of digesta in the caecum than to its retention time in the whole digestive tract (Sakaguchi *et al.*, 1987). No selective retention of digesta is observed in the guinea-pig. Liquid and particle digesta move together through the gastrointestinal tract. This movement of digesta can be considered to be advantageous in the digestion of fibre (Hume and Sakaguchi, 1991).

If the digestive tracts of the South American rodents function in a similar way to those of the guinea-pig and mara, digestibility of fibre should be effective in the degu and leaf-eared mouse. However, no information is available in which digestibilities were actually determined. Therefore, the following study was undertaken to compare the digestibility of fibre and the retention time of digesta in the gastrointestinal tract in the guinea-pig, degu and leaf-eared mouse.

MATERIALS AND METHODS

Animals and feeding

Five adult male guinea-pigs (mean body mass 498 g), four male and four female degus and three male and three female leaf-eared mice were used. All animals were housed individually in stainless steel mesh cages, 0.36 m diameter × 0.3 m high for guinea-pigs and 0.15 × 0.20 × 0.17 m high for degus and leaf-eared mice.

Markers of liquid and solid digesta were mixed with a small amount of the experimental diet and given 2 hr after the digestion trials. The animals were starved for 2 hr before they were given the markers.

During the experiments all animals were given an experimental cubed diet containing lucerne (*Medicago sativa*) meal *ad lib*. The composition of the experimental diet is shown in Table 1. The feed consumption of each animal was recorded daily. Feed and water were available freely in both periods and coprophagy was not prevented so that feeding habits were as normal as possible.

Collection procedures

Faeces to determine digestibilities of feed were collected daily during the last 5 or 6 days in digestion trials after 5 days pre-collection period of experiment.

Faecal samples to determine the retention time of digesta were taken every 2 hr for the first 14 hr, every 4 hr for the next 16 hr, every 6 hr for the next 12 hr and every 8 hr for the further 32 hr after dosing of the markers for the degus and leaf-eared mouse. Faecal samples were taken every 2 hr for 14 hr, every 4 hr for the next 8 hr, every 6 hr for the next 24 hr and every 8 hr for a further 48 hr after dosing for the guinea-pig.

Digesta markers

Cr-mordanted Italian ryegrass (*Lolium multiflorum* L.) cell-wall constituents (Cr-CWC) as a particle marker and Co-EDTA as a liquid digesta marker were used to estimate retention time. Cr-CWC were prepared by the methods of Udén *et al.* (1980). Cr-CWC was ground to a coarse particle size and passed through a 40 mesh screen. The resulting particles were then passed through a 20 mesh screen and those which remained on the screen were used in the

Table 1. Composition of experimental diet (g/kg)

Ingredients	(g/kg)
Lucerne (*Medicago sativa*) meal	500
Defatted milk powder	150
Wheat bran	150
Maize oil	50
Maize	50
Sucrose	50
Mineral mix*	30
Vitamin mix†	20
Analysis	
Moisture	50
Organic matter	875
Crude protein (nitrogen × 6.25)	178
Diethyl ether extracts	79
Crude fibre	137
NDF	303
ADF	173
Crude ash	76
Non-fibrous matter‡	647

*Composition (mg/kg mixture): 145.6 $CaHPO_4 \cdot 2H_2O$, 257.2 KH_2PO_4, 93.5 $NaH_2PO_4 \cdot H_2O$, 46.6 NaCl, 350.9 Ca-lactate, 31.4 Fe-citrate, 71.7 $MgSO_4$, 1.1 $ZnCO_3$, 1.2 $MnSO_4 \cdot 6H_2O$, 0.3 $CuSO_4 \cdot 5H_2O$, 0.1 KI. †Composition (mg/kg mixture): 1000 retinol acetate, 2.5 cholecalciferol, 1200 thiamin hydrochloride, 4000 riboflavin, 800 pyridoxine hydrochloride, 0.5 cyanocobalamin, 30,000 ascorbic acid, 5000 tocopherol acetate, 5200 menadione, 20 D-biotin, 200 pteroylmonoglutamic acid, 5000 calcium pantothenate, 50,000 *p*-aminobenzoic acid, 6000 nicotinic acid, 6000 inositol, 200,000 choline chloride, 730,577 cellulose powder.
‡The value was calculated by subtracting the value of NDF from the value of dry matter.

experiment. The diameter of the particles was in the range 0.381–0.840 mm and the length was shorter than 5 mm.

Analytical methods

The pooled faecal samples from the digestion trials were oven dried at 60°C, then ground and analysed for dry matter, crude fibre, crude ash, total nitrogen (AOAC, 1975), neutral-detergent fibre (NDF) and acid-detergent fibre (ADF) by methods described by Van Soest and Wine (1967) and Van Soest (1963), respectively. Organic matter was determined by subtracting ash from dry matter.

To determine concentrations of Cr and Co, faecal samples were oven-dried at 60°C and ashed at 550°C for 5 hr. The ashed samples were treated according to the method described by Williams *et al.* (1962). Analysis of Cr and Co in the treated sample was made by atomic absorption spectroscopy (atomic absorption spectrophotometer AA-80; Nippon Jarrell-Ash, Kyoto).

Calculations

Single exponential regression equations were fitted statistically to the time-course decline of the faecal concentrations of Cr and Co in all of the animals. A turnover time of each marker was estimated from the decline in faecal concentration of marker by the function (Brandt and Thacker, 1958):

$$Y = Y_0 \times e^{-kt}$$

where Y is the concentration of Cr or Co in faeces at time t, Y_0 is the constant depending on the level of Cr or Co fed, k is the rate constant and t is the time interval after feeding of the markers (hr). Turnover time was calculated as the reciprocal of the rate constant (k) if the exponential curve fitted to the time-course excretion values of the markers after faecal marker concentration reached a maximum. Total mean retention time (MRT) in the gastrointestinal tract was calculated as the sum of the reciprocal of k and transit time (TT) equal to the first appearance of the marker after a dose.

Statistics

The data were analysed as a single factorial design and tested for statistical difference by Duncan's multiple-range test (Duncan, 1955). Differences between the mean values of particle and liquid marker were evaluated by Student's t-test (Snedecor and Cochran, 1967).

RESULTS

Feed intake and digestibility (Table 2)

The guinea-pigs gained weight, whereas the degus slightly lost weight. The leaf-eared mice almost maintained their weight during the experimental period. Daily feed intake on a metabolic body size (per kg body wt$^{0.75}$) basis was not significantly different between animals. However, the degu had less amount of feed than the other two species.

Apparent digestibilities of dry matter, organic matter and fibre components (NDF, ADF and crude fibre) and crude ash are highest in the guinea-pig followed by the degu and lowest in the leaf-eared mouse. However, the digestibilities of crude fat and non-fibrous matter were significantly higher in the degu and leaf-eared mouse than in the guinea-pig.

Table 2. Body wt, feed intake and apparent digestibilities of feed in the guinea-pig, degu and leaf-eared mouse

	Guinea-pig ($N = 5$)	Degu ($N \pm 8$)	Leaf-eared mouse ($N \pm 6$)	SE of mean
Body weight (g)				
Initial	498*	177†	81‡	15
Daily gain	6.6*	−1.1†	0.2†	1.6
Feed intake (g/kg$^{0.75}$/day)	52.8*	37.6*	57.8*	7.1
Digestibility (%):				
Dry matter	73.0*	69.9*	65.9†	1.3
Organic matter	73.3*	71.6*	67.8†	1.3
Crude protein	72.6*	72.6*	73.4*	1.8
Crude fat	82.1*	87.8†	88.1†	0.8
NDF	51.5*	47.1†	40.0†	2.9
ADF	44.3*	34.9†	24.4†	3.9
Crude fibre	40.5*	33.3†	18.3†	5.1
Crude ash	70.3*	49.9†	43.4‡	1.6
Non-fibrous matter§	80.4*	84.7†	82.9†	0.7

*†‡Mean values in the same horizontal row with different symbols are significantly different ($P < 0.05$). §The value was calculated by subtracting the value of NDF from the value of dry matter.

Table 3. Measures of retention of digesta markers in the guinea-pig, degu and leaf-eared mouse

	Guinea-pig ($N = 5$)	Degu ($N = 8$)	Leaf-eared mouse ($N = 6$)	SE of mean
Particle (Cr)				
$1/k$	12.1*	10.3*	2.6†	1.9
TT	5.0*	5.1*	6.1*	1.2
MRT	17.1*	15.5*	8.8†	2.6
Fluid (Co)				
$1/k$	15.4*	14.2*	5.3†‡	2.3
TT	5.0*	5.2*	3.8*	1.1
MRT	20.4*	19.4*	9.1†	3.3

Particle marker is Cr-mordanted CWC (Udén *et al.*, 1980). Fluid marker is Co-EDTA.
k is a rate constant which is the dilution rate per hr of the marker in the digestive tract. TT (transit time) is the time-interval between feeding and first appearance of the marker in the faeces. MRT is the sum of $1/k$ and TT.
*†Mean values in the same horizontal row with different symbols are significantly different ($P < 0.05$). ‡Significantly different from the particle marker ($P < 0.01$).

The digestibility of crude protein is not different between the animal species.

Retention of digesta markers (*Table* 3)

The single exponential equation could be fitted to all the time-course decline of faecal concentration of the markers in all animals. The marker excretion patterns were generally smooth and no significant difference can be detected between Cr and Co in the guinea-pig and degu. However, the turnover time which is the reciprocal of k ($1/k$) of particle marker was significantly shorter than that of fluid marker in the leaf-eared mouse. There was no significant difference between the guinea-pig and degu in the value of $1/k$ and MRT. However, both the values were somewhat larger in the guinea-pig than in the degu. The transit time (TT) which means time interval between feeding and first appearance of the marker in the faeces was not significantly different between the three species. The values of $1/k$ and MRT were significantly smaller in the leaf-eared mouse than in the guinea-pig and degu.

DISCUSSION

The guinea-pig gained weight but the degu lost weight, while the leaf-eared mouse maintained their weights in the experimental period. This should correlate to the lower intake of feed per unit body mass ($kg^{0.75}$) in the degu than in the guinea-pig and leaf-eared mouse.

The guinea-pig digested fibre component (NDF, ADF and crude fibre) most efficiently among the three animals. The animals which belong to the family of cavies, guinea-pig and mara (*Dolichotis patagonum*) possess a similar function of fibre digestion and the site, pattern and rate of digesta retention are very similar in the two species, furthermore both animals appear to lack any selective retention of fluid or fine particles (Sakaguchi *et al.*, 1992). The guinea-pig is more efficient in the digestion of fibre and its components than rabbits, hamsters and rats (Sakaguchi *et al.*, 1987). This suggests that the pattern of digesta flow in the guinea-pig and mara is advantageous for the digestion of fibre.

In the guinea-pig, the digesta are retained mainly in the caecum and upper proximal colon (Sakaguchi *et al.*, 1985). When the digesta markers are injected into the caecum, the rate constant of marker dilution in the caecal contents agrees with that in the faeces. Furthermore, the rate constant of marker dilution in the faeces after oral application agrees closely with that in caecal and that in the faeces after caecal injection (Sakaguchi *et al.*, 1986). These findings suggest that the dilution rate of marker in the faeces can be regarded as a reflection of marker dilution in the caecum after oral application. The retention time of digesta in the large intestine (mainly caecum) can, therefore, be calculated from the faecal values for marker excretion in the guinea-pig.

The degu is a herbivorous rodent, which belongs to a suborder of the cavies. The young are fully haired and almost completely developed at birth like the young of guinea-pig. In this experiment the degu consumed less amount of feed than the other two animal species and lost weight. The diet used in this experiment does not seem agreeable to the palate of the degu.

The pattern of digesta flow is similar to that of the guinea-pig in the degu. However, the retention time of digesta was shorter (no statistical significance) than that of the guinea-pig, which subsequently led to lower digestibilities of fibre components. The difference in MRT of digesta between the three animals can be considered to be connected with the difference in their body mass because the retention time of digesta tends to increase with body size for species having similar food habits from the same vertebrate class, as discussed by Karasov *et al.* (1986).

The capacity of the digestive tract is regressed against body wt for herbivores (Demment and Van Soest, 1983). In relation to this, a linear relation is observed between the body wt and the retention time of digesta in the gastrointestinal tract in several rodents (Sakaguchi, 1991).

Lower intake per unit body mass may result in a prolonged retention time, and hence a higher digestibility of fibre. The lower intake of feed in the degu in the experiment could be thought to cause a somewhat higher digestibility of fibre than that expected when the degu consumed a similar amount of feed per unit body mass as the guinea-pig and leaf-eared mouse.

The lower digestibility of fibre in the leaf-eared mouse must be connected with the shorter retention time of digesta. The retention time of the particle marker was shorter than that of liquid marker. Such a delay of excretion of liquid digesta compared with the particle digesta was also observed in the hamster (*Mesocricetus auratus*) (Sakaguchi *et al.*, 1987). However, the possible selective retention of liquid digesta in these animals is not as definite as that in the rabbit. At any rate, the guinea-pig and degu do not possess such a function in the gastrointestinal tract.

The lower digestibility of crude ash and fibre components might result in the lower digestibility of dry matter in the leaf-eared mouse, however the digestibility of non-fibrous matter was higher in the two animals than in the guinea-pig. The digestibility of crude protein was similar in the three animals. This means that non-fibrous and non-nitrogenic substances were digested well by the leaf-eared mouse. A

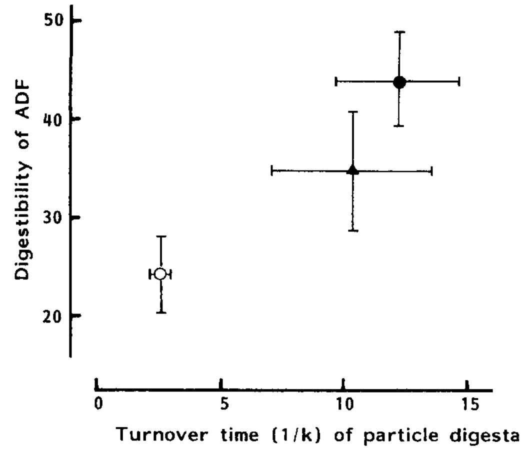

Fig. 1. Digestibilities of acid-detergent fibre (ADF) and turnover time of particle digesta in guinea pigs ($N = 5$, ●), degus ($N = 8$, ▲) and leaf-eared mice ($N = 6$, ○). Points are mean values and their standard deviations are represented by bars. The values were obtained from Tables 2 and 3.

larger extent of microbial digestion might result in a larger loss of the non-fibrous organic matter in the guinea-pig.

The plots of the mean values of the digestibility of ADF and turnover time ($1/k$) of particle marker and metabolic body size ($kg^{0.75}$) for each species (Figs 1 and 2), shows a linear relationship between the digestibility of ADF and $1/k$ of the particle digesta, and between the digestibility of ADF and the metabolic body size. This suggests that the value of $1/k$ represents the turnover time of particle digesta in the large intestine in the three animals and also shows that the close relationship between the body wt, volume of digestive tract, retention time of digesta and digestibility of fibre.

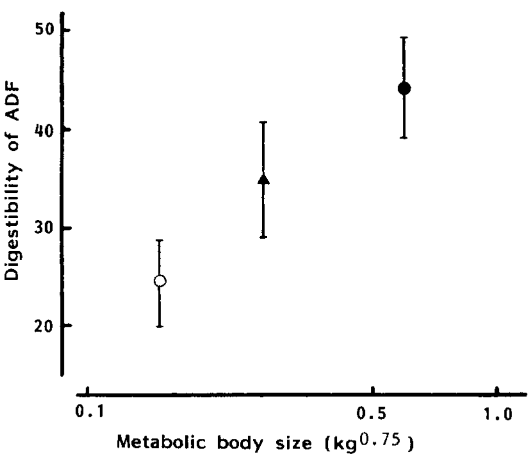

Fig. 2. Digestibilities of acid–detergent fibre (ADF) and metabolic body size ($kg^{0.75}$) in guinea pigs ($N = 5$, ●), degus ($N = 8$, ▲) and leaf-eared mice ($N = 6$, ○). Points are mean values and their standard deviations are represented by bars. The standard deviation of the body size is not shown in the figure, because the value was very small in each animal species. The values were obtained from Tables 2 and 3.

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