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# COMPARISON OF FIBRE DIGESTION AND DIGESTA RETENTION TIME BETWEEN NUTRIAS (*MYOCASTER COYPUS*) AND GUINEA-PIGS (*CAVIA PORCELLUS*)

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**Abstract**—1. Digestibilities of feed, and transit and retention time of fluid and particle digesta marker measured in nutrias (*Myocaster coypus*) and guinea-pigs (*Cavia porcellus*) fed on a diet containing 50% alfalfa.

2. The digestibility of fibre was higher in the nutria, along with the longer retention time of digesta.

3. The liquid and particle marker were similarly excreted, suggesting no separation mechanism in the gastrointestinal tract of both the animals.

4. The apparent digestibility of protein in the nutria was superior to the guinea-pig and other small hindgut fermenters, suggesting that the contribution of coprophagy on protein nutrition of nutrias is significant.

## INTRODUCTION

Nutrias and guinea-pigs are herbivorous rodents native to South America and classified as hindgut fermenters which have a well-developed large intestine. It is well known that the hindgut fermenters have a wide range of body size and a variety of digestive strategies (Clemens and Stevens, 1980). It has been shown that guinea-pigs have a voluminous caecum and colon, and can retain digesta in the large gut for a considerable time without any mechanisms to separate fluid and particles (Sakaguchi *et al.*, 1985, 1986). This is regarded as one of the factors which activate the digestion of fibre by intestinal microbes (Sakaguchi *et al.*, 1987). It has been reported, that fibre components are digested in the guinea-pig as efficiently as in horses and ponies (Slade and Hintz, 1969). However, a considerable linear relationship has been observed between body wt and retention time of digesta in the gastrointestinal tract in small hindgut fermenters, including guinea-pigs. The retention time and transit time of digesta does not necessarily reflect the efficiency of fibre digestion (Sakaguchi, 1991).

Regional differences in the function and structure of hindgut and digesta retention time in the nutria has been described (Snipes *et al.*, 1988; Gill and Bieguszewski, 1960). However, very little information regarding the function of the digestive tract other than the above-mentioned studies are available. Although, the morphological and physiological aspects investigated in the reports suggest that nutria has the reasonable functions of the large intestine appropriate to its nutritional strategy as an exclusively herbivorous rodent.

The objective of this study was to define the performance of fibre digestion and digesta flow in the digestive tract of nutria in comparison with the guinea-pig.

## MATERIALS AND METHODS

### *Animals and feeding*

Six adult nutrias (mean body mass 4.4 kg) and five adult guinea-pigs (1.0 kg) were used. All animals were housed individually in stainless steel mesh cages, each 0.52 × 0.73 × 0.55 m high for nutrias and 0.36 m diameter × 0.3 m high for guinea-pigs.

Food and water were freely available in both periods. Coprophagy was not prevented so that feeding habits were as normal as possible. 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.

Food consumption of each animal was recorded daily. Faeces were collected daily during the last 4 or 5 days in digestion trials (for determination of digestible efficiency) after 5 or 6 days pre-collection period of experiment.

To determine the retention time of liquid and particle digesta in the intestine, digesta markers were administered orally after the digestion trials. Faecal samples of each animal were taken every 2 hr for the first 24 hr, every 4 hr for the next 28 hr and every 8 hr for the further hr after dosing. The collection period was 7 ~ 10 days for the nutria and 5 days for the guinea-pig.

### *Digesta markers*

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

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

| Ingredients | (g/kg) | Analysis | |
|---|---|---|---|
| Lucerne (*Medicago sativa*) meal | 500 | Moisture | 89.0 |
| Defatted milk powder | 150 | Dry matter | 911.0 |
| Wheat bran | 150 | Organic matter | 833.6 |
| Soy bean oil | 50 | Crude protein | 134.5 |
| Soy bean | 50 | NDF | 325.0 |
| Sucrose | 50 | ADF | 213.9 |
| Mineral mix* | 30 | Crude ash | 77.4 |
| Vitamin mix† | 20 | Non-fibrous contents | 586.0 |

*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 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.

Crude protein: nitrogen × 6.25.
NDF: neutral detergent fibre (Van Soest and Wine, 1967).
ADF: acid detergent fibre (Van Soest, 1963).
Non-fiberous contents: dry matter—NDF.

These prepared samples were analysed for dry matter, crude ash and total nitrogen (AOAC, 1980) and for neutral-detergent fibre (NDF) and acid-detergent fibre (ADF) using the methods described by Van Soest and Wine (1967) and Van Soest (1963), respectively. Organic matter was determined by subtracting ash from dry matter. The digestibilities of each animal was calculated.

To determine the retention time, the faecal concentrations of Cr and Co were analysed. Faecal samples collected time-sequentially were oven-dried at 60°C and weighed, then ashed individually at 600°C for 8 hr. The ashed samples were treated according to the method described by Williams *et al.* (1962). Analysis of Cr and Co in the treated samples were made with 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 nutrias and guinea-pigs. A turnover time of each marker was estimated from the decline in faecal concentration of marker by the function (Brandt and Thacker, 1958):

$$Y = Y_0 e^{-kt},$$

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 dosing of the markers (h). Turnover time of fermentation chamber (caecum and proximal colon) 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 the transit time (TT). TT was considered equal to the first appearance of the marker after dosing.

Table 2. Apparent digestibilities of feed in the guinea-pigs and nutrias (g/100 g)

| | Guinea-pig ($N = 5$) | | Nutria ($N = 6$) | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Dry matter | 64.88 | 3.96 | 70.94* | 2.75 |
| Organic matter | 64.68 | 3.35 | 72.13† | 2.66 |
| Crude protein (nitrogen × 6.25) | 59.52 | 3.47 | 76.65† | 2.22 |
| NDF | 38.40 | 4.96 | 47.68* | 6.61 |
| ADF | 30.70 | 9.51 | 41.88* | 6.35 |
| Non-fibrous contents (DM—NDF) | 77.77 | 3.13 | 83.11† | 2.28 |

NDF: neutral detergent fibre (Van Soest and Wine, 1967).
ADF: acid detergent fibre (Van Soest, 1963).
*, †: Mean values are significantly different from the guinea-pig ($P < 0.05$, $P < 0.01$, respectively).

Table 3. Turnover time, transit time and mean retention time (hr) of particle and liquid digesta markers in the guinea-pig and nutria

| | Guinea-pig ($N = 3$) | | Nutria ($N = 5$) | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Particle (Cr-CWC) | | | | |
| Turnover time ($1/k$) | 25.69 | 10.76 | 39.21 | 22.09 |
| Transit time (TT) | 5.00 | 2.00 | 5.80 | 3.03 |
| MRT ($1/k$ + TT) | 30.69 | 12.05 | 45.01 | 20.85 |
| Liquid (Co-EDTA) | | | | |
| Turnover time ($1/k$) | 18.24 | 2.74 | 39.17 | 21.61 |
| Transit time (TT) | 4.33 | 1.15 | 5.00 | 2.45 |
| MRT ($1/k$ + TT) | 22.58 | 1.91 | 44.17 | 20.68 |

$k$: rate constant of the marker in the pool of the digestive tract.
TT: time-interval between feeding and first appearance of the marker in the faeces (transit time).
MRT: mean retention time of whole digestive tract.

The excretion curves of markers in the nutria and guinea-pig were almost smooth (Fig. 1). There was no significant difference in the values of $1/k$, TT and MRT ($1/k$ + TT) between particle marker (Cr) and liquid marker (Co) in both animals. The values of $1/k$ and MRT both of the particle and liquid marker were longer in the nutria than in the guinea-pig (Table 3), although the difference was not significant because of the large variation of the data in the nutria.

*Distribution of crude protein concentration of digesta*

After determination of retention time of digesta, animals were slaughtered by an intraperitoneal injection of excess amount of sodium pentobarbital (Abbott Laboratories, North Chicago, IL, U.S.A.) and the digesta of stomach, caecum, proximal colon and distal colon was collected. The concentrations of crude protein in the samples of digesta were analysed.

*Statistics*

Differences between the mean values were evaluated statistically by Student's $t$-test (Snedecor and Cochran, 1967).

## RESULTS

*Digestibility of feed (Table 2)*

Apparent digestibilities of fibre components (NDF and ADF) were significantly ($P < 0.05$) higher in the nutrias than in the guinea-pigs. The digestibility of crude protein was also significantly ($P < 0.01$) higher in the nutrias. This difference between values of crude protein was remarkable.

*Retention of digesta markers (Table 3, Fig. 1)*

*Distribution of crude protein concentration of digesta in the nutrias (Table 4)*

Four nutrias were used in this analysis. One of them was considered to be during or just after coprophagy, because several faeces-like pellets were in the stomach of the animal. Therefore this data is shown separately. Furthermore, the concentration of

crude protein in the digesta of the stomach and distal colon was much higher in the animal than in the other three animals.

## DISCUSSION

There were no differences in the values of the retention time between particle marker (Cr) and liquid marker (Co) in both animals. This finding suggests both animals lack any selective retention of digesta in the gastrointestinal tract. The large intestine of the South American rodents, guinea-pigs, maras (*Dolichotis patagonum*) and degus (*Octodon degus*) retain digesta without selective retention (Sakaguchi *et al.*, 1985, 1986; Sakaguchi, 1991) resulting in efficient digestibility of fibre. The result of this experiment suggests that the large intestine of nutrias also has a similar pattern of the retention of digesta to that in these animals.

The values of the digestibilities of fibre components and the retention time in the whole tract are higher in nutrias. Generally, the digestibility of fibre components in small herbivores is closely related to the retention time of digesta in the fermentation chamber, caecum or colon (Sakaguchi, 1991). However, considerably long retention time and high digestibility of fibre are observed in the nutrias in this experiment. The great difference of the retention time between the nutria and the guinea-pig (45.0 and 30.7 hr, respectively) cannot be illustrated from the daily food intake (guinea-pigs: 51 g/kg body wt, nutrias: 31 g/kg body wt) and volumes of caecum and proximal colon regarded as a fermentation chamber (5.3% and 2.7% of body wt, respectively). Thus, it is necessary to consider any other function which prolongs the retention time of digesta rather than food intake and volume of the intestine. It has been observed that the nutria raised as a domestic animal was coprophagous (Gosling, 1979; Snipes *et al.*, 1988). The long retention time in this experiment could be considered to be due to the circulation of digesta through the mouth in the gastrointestinal tract by coprophagy. It may also result in high digestibility of fibre.

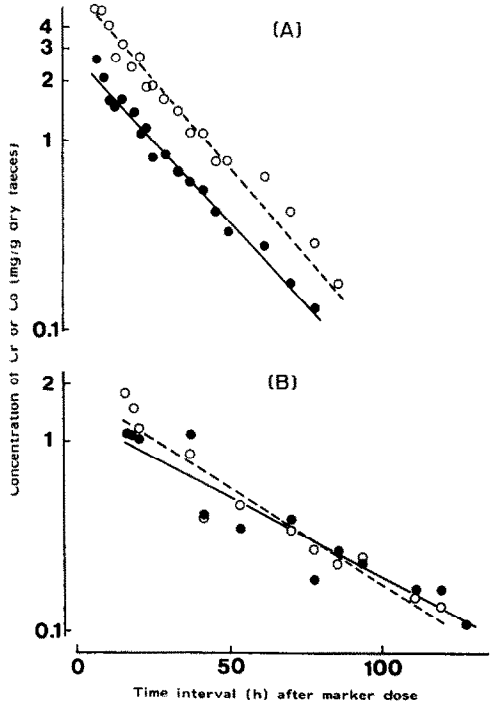


Fig 1. Time sequence change of the concentrations of markers in the faeces following an oral dose in one example for each of the animal species studied: (A) guinea-pig and (B) nutria. Cr-mordanted cell wall contents (●) and Co-EDTA (○) were given as the marker of intestinal digesta. The regression lines (Cr: ——; Co: -----) of the time-course reductions in concentrations of Cr and Co are expressed as $Y = Y_0 e^{-kt}$, where $Y$ is the concentration of Cr or Co 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). The values of $Y_0$ and $k$ for Cr are 2659.8, 0.041 for the guinea-pig and 1354.6, 0.020 for the nutria. The values of $Y_0$ and $k$ for Co are 6433.4, 0.048 for the guinea-pig and 1820.9, 0.025 for the nutria.

Table 4. Crude protein concentrations of digesta in gastrointestinal tract in the nutrias (g/100 gDM)

| | Guinea-pig ($N = 3$) | Nutria ($N = 4$) Total ($N = 4$) | High* ($N = 1$) | Low† ($N = 3$) |
|---|---|---|---|---|
| Diet | 16.7 | 16.7 | — | — |
| Stomach | 27.3 | 16.7 | 25.1 | 13.9 |
| Caecum | 30.8 | 20.6 | 22.6 | 19.9 |
| Proximal colon | 19.1 | 12.2 | — | 12.2 |
| Distal colon | 21.7 | 17.8 | 29.9 | 13.8 |
| Faeces | 17.5 | 13.8 | — | — |

*Animal of which contents in the stomach were rich in protein.
†Animals of which contents in the stomach were lower in protein.

Crude protein concentrations of digesta in the stomach and distal colon were extremely high in one of the four nutrias investigated. This animal can be regarded to be involved in coprophagy, and the protein rich digesta present in the distal colon should be reingested. Therefore, this observation suggests that the nutria produce two kinds of faeces different largely in crude protein concentration. The protein rich faeces must be selectively ingested by the nutria. Snipes *et al.* (1988) observed the accumulation of nitrogen in caecal contents, and suggests the existence of a separation process involving a specific motility (retrograde transport).

As mentioned above, generally, the close relationship between digestibility of fibre contents and retention time of digesta in the fermentation site has been detected in the hindgut fermenters. For further discussion upon this point, the data of the digestibility of ADF and the turnover time ($1/k$) of particle digesta marker obtained previously in several hindgut fermenters (Sakaguchi *et al.*, 1985, 1986; Sakaguchi, 1991) are plotted together with the data obtained in this study on the same diet in Fig. 2. The turnover time is regarded as the mean retention time of digesta in the fermentation chamber.

Close correlation can be detected between the digestibility of ADF and the turnover time of digesta. This suggests in general the retention time of digesta in the fermentation site is an important factor related to the degree of bacterial digestion. It is also suggested that the digestion of fibre is governed by the retention time of digesta in the fermentation chamber among small hindgut fermenters. According to this concept, the high digestibility of fibre in

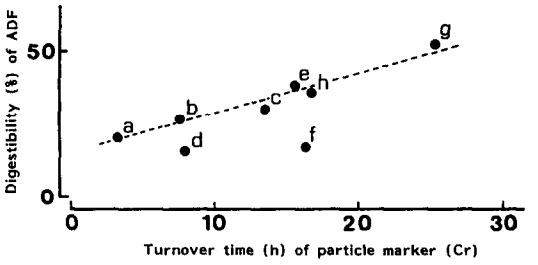


Fig. 2. Digestibilities of acid detergent fiber (ADF) and turnover time ($1/k$) of particle marker (Cr-CWC) in the gastrointestinal tracts in (a) leaf-eared mice, (b) hamsters, (c) degus, (d) rats, (e) guinea-pigs, (f) rabbits, (g) nutrias and (h) maras. The regression line (---, $r^2 = 0.98$) does not include the data of rats and rabbits.

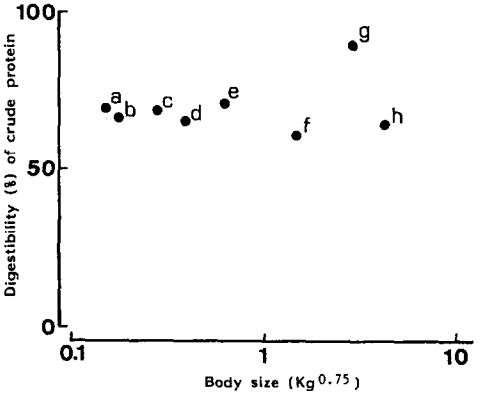


Fig. 3. Digestibilities of crude protein and metabolic body size ($kg^{0.75}$) in (a) leaf-eared mice, (b) hamsters, (c) degus, (d) rats, (e) guinea-pigs, (f) rabbits, (g) nutrias and (h) maras.

the nutrias can be illustrated by a relatively long retention time.

To examine the relationship between the body wt and the digestibility, the digestibility of crude protein and metabolic body size in the same small hindgut fermenters are plotted in Fig. 3. No relationship between body size and digestibility of nitrogen in the small herbivores, and other animals exist except the nutria which have similar values of digestibility regardless of body size, although the nutria has a very high value. This suggests that the digestibility of crude protein in the nutria is superior to the other species. The higher efficiency of digestion of protein must be caused by the re-ingestion of the protein rich digesta through coprophagy.

In conclusion, it is considered that the nutria has a large voluminous intestine which acts as an effective fermentation chamber with no selective retention of digesta. The voluminous large bowel results in long retention time of digesta connected with high digestibility of fibre. Furthermore, the coprophagy which causes higher digestibility of protein can be considered to be important in the protein nutrition of the nutria.

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