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Digestive tract morphology and food habits in six species of rodents

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A b s t r a c t . To investigate the relationship between food habits and digestive tract morphology, the lengths of gastrointestinal tracts of six species of rodents with different food habits were compared. The results showed that the strict herbivores, *Microtus brandti*, had the largest large intestine and ceacum, and the tracts of the other five granivorous/omnivorous species (*Spermophilus daurica, Phodopus robovskii*, *Cricetulus barabensis*, *Cricetulus triton*, *Meriones unguiculatus*) varied to different extents depending on the proportions of seed, vegetative and animal foods in their diets. Small intestine lengths did not reflect diet fiber content for these six rodent species and stomach lengths in granivorous/omnivorous rodents were not larger than herbivores. Our results suggest that the hind gut is more important for herbivorous than for granivorous/omnivorous rodents and could be a relative reliable indicator for food habits, however, small intestine is not a good indicator for food habits. This study also showed that there is no direct relationship between life history traits and gut morphology in these six rodent species, although more life history traits should be considered.

Key words: gastrointestinal tract, life history trait, small mammals

Introduction

The acquisition and effective processing of food energy is critical to the survival and reproductive success for animals (K a r a s o v 1986, D e r t i n g & B o u g e 1993). Digestive tract morphology can affect digestive efficiency and is closely related to food habits. Differences in food habits among mammals are often reflected in the structure of their alimentary tract (E l l i s et al. 1994). V o r o n t s o v (1962) has observed differences in digestive tract morphology to evolutionary adaptations for a herbivorous diet. The transition from a high-energy, high-protein, and high-lipid diet of seeds and small invertebrate, to a low-energy, high-cellulose diet of vegetative parts of plants was hypothesized to have resulted in several evolutionary modifications in the digestive tracts of muroid rodents. V o r o n t s o v (1962) listed some of evolutionary trends among the rodentia as adaptations for herbivorous digestive tract: 1). Increase in total digestive tract capacity; 2). Reduction in the relative length of the small intestine; 3). Increase in relative size of the caecum and colon.

The primary aim of the present study was to compare the digestive tract morphology of six rodent species, and relate these observations to their life history patterns. The six rodent species include one strict herbivores, Brandt't vole (*Microtus brandti*), which feeds on leaves, stems and roots of grass and herbs; four omnivorous species, ground squirrel (*Spermophilus daurica*), desert hamster (*Phodopus robovskii*), striped hamster (*Cricetulus barabensis*), and greater long-tailed hamster (*Cricetulus triton*).Ground squirrels feeds mainly on leaves and stems of plants and invertebrates (herbivorous-omnivore) , whereas the other three species feed mainly on plant seeds and invertebrates (granivorous-omnivores);

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and one granivorous species, Mongolian gerbil (*Meriones unguiculatus),*which feeds mainly on plant seeds, but in late spring and summer because granivorous herbivore also feeds on some leaves and stems of plants (Z h o u et al. 1990, B a o 1998, Z h a n g & W a n g 1998).

According to Vorontsov's hypothesis, species consuming the vegetation (especially strict herbivores) can be predicted to show the following properties: 1) a relative longer digestive tract; 2) a higher proportion of large intestine and cecum to the length of the total digestive tract; and 3) a shorter proportion of small intestine; whereas those with adaptations to a granivorous and/or omnivorous diet will posses nearly converse characteristics in gut adjustments. Thus, *Microtus brandti* should be expected to have relative greater gut capacity than the other five species.

Material and Methods

Spermophilus daurica, Phodopus robovskii, *Cricetulus barabensis*, and *Microtus brandti* were trapped by snap-trap and *Meriones unguiculatus* by live traps in Inner Mongolia grassland. *Cricetulus triton* was live trapped in the farmland of Hebei Province, Northern China, in July and August 1998. All animals sampled in this study were adults and without obvious pregnancy and lactation. Upon capture, all animals were carried to the field laboratory and the live animals were killed, and the sex, reproductive status and body mass were checked, weighted and recorded.

The entire digestive tract of animals were removed, carefully stripped the connective tissues and lipids, then extended to their full length without stretching on a dissecting plate, and the lengths of the stomach, small intestine, large intestine, and cecum were measured to the nearest 1 mm. All statistical analysis of data was conducted using SPSS statistical package. In order to remove the effect of body mass, analysis of covariance (ANCOVA) was used to analyze the data, using body mass as the covariate, and followed by least significant difference (LSD) multiple comparisons. For all statistical tests, differences among species were considered statistically significant at $P< 0.05$.

Results

S. daurica had the largest length of small intestine and *P. robovskii* had the smallest one (ANCOVA, Table 1). No significant differences were found between *C. barabensis, Me. unguiculatus*, and *C. triton* ($P>0.05$) and between *P. robovskii* and *M. brandti* as well ($P>0.05$). *S. daurica, C. barabensis*, and *C. triton* had longer stomachs than *P. robovskii,*

Table 1. The mean measurements of digestive tract for six species of rodents(±SD) (means and SDs are adjusted values from ANCOVA analysis; Absolute values are given in the Appendix).

Species	Sample size	Body mass (g)	Stomach (cm)	Small intestine (cm)	Large intestine (cm)	Cecum (cm)	Total GI (cm)
Microtus brandti	8	34.0±3.8	2.8±0.3	30.5±3.4	23.8±1.6	13.7±0.8	70.9±4.5
Spermophilus daurica	9	151.2±22.2	4.6±0.5	70.3±5.2	21.0±2.5	5.5±1.2	101.4±6.8
Cricetulus triton	8	120.2±9.6	4.3±0.3	45.2±3.3	20.5±1.6	5.7±0.8	75.6±4.4
Cricetulus barabensis	8	23.9±4.1	3.7±0.4	37.8±4.1	15.3±2.0	7.6±0.9	64.3±5.4
Meriones unguiculatus	5	48.6±8.6	2.6±0.3	37.5±2.9	14.6±1.4	6.0±0.7	60.7±3.9
Phodopus robovskii	4	15.0±4.9	2.6±0.5	28.1±5.4	12.6±2.6	5.0±1.2	48.3±7.1

Microtus brandti, and *Me. unguiculatus* ($P<0.05$); *S. daurica* had the longest stomach and *Me. unguiculatus* had the shortest one, but no differences were found between *S. daurica, C. barabensis*, and *C. triton* ($P>0.05$), and between *P. robovskii, M. brandti*, and *Me. unguiculatus* ($P>0.05$). *S. daurica, M. brandti*, and *C. triton* had longer large intestines than did *C. barabensis*, *P. robovskii* and *Me. unguiculatus* ($P<0.05$). *M. brandti* had the longest large intestine and *P. robovskii* had the shortest one, but no significant differences were found between *S. daurica*, *M. brandti*, and *C. triton* ($P>0.05$), and between *C. barabensis, P. robovskii* and *Me. unguiculatus*($P>0.05$). The cecum was also the longest in *M. brandti* and the shortest in *P. robovskii.* No differences were found between *S. daurica, P. robovskii*, *Me. unguiculatus*, and *C. triton* ($P>0.05$).

Discussion

Of the six rodent species studied *M. brandti* had the longest caecum and large intestine, and the length of their small intestine does not reflect the fiber content of their diets. In some rodent species, the estimated volume and surface area of the caecum and colon were greater in the herbivorous species than that in the granivorous species (Barry 1977). And food habit may be closely related to gut morphology and structure (Wilczynska 1998, 1999). Schieck & Millar (1985) compared the digestive tract morphology for 35 species of rodents and also found that the masses and lengths were greater in herbivores than in granivores, and stated that small intestine lengths in small mammals did not reflect the amount of fiber in the diet of each species. But significant differences were not found in measurements of the small intestine in white-footed mouse (*Peromyscus leucopus*) - an omnivorous species, and meadow vole (*Microtus pennsylvanicus*) - a herbivorous species, the hind gut measurements revealed diet-specific anatomical differences (Derting & Noakes 1995).

Generally, because of their high quality and nonfibrous diets, omnivorous and granivorous species do not depend upon post-gastric fermentation chambers for the storage of digesta and for nutrient extraction; the protein and easily digestible carbohydrates can be processed and the nutrients absorbed in the foregut, and consequently, it can feed intermittently using its relatively large stomach as a storage chamber for food and still meet its daily energy needs (Derting & Noakes 1995). In the present study, the lengths of stomach were longer in *S. daurica* and *C. triton* than in other species. The herbivorous *M. brandti* has similar stomach length to the granivorous-herbivorous *Me. unguiculatus* and granivorous-omnivorous *P. robovskii*. This is somewhat not in consistent with the general trend. However, Derting & Noakes (1995) found that *P. leucopus* has a longer stomach than *M. pennsylvanicus*. In contrast to granivorous and omnivorous species, herbivorous species rely upon a more continual flow of their low quality, highly fibrous diet throughout the anterior portion of the gut prior to retention, fermentation, and assimilation of nutrients in the cecum and colon (Demment & Van Soest 1985, Hume 1994). Therefore, with a more continual feeding pattern and the use of postgasric fermentation, the capacity of the caecum is likely to be of greater importance than that of other gut organs in herbivorous rodent (Derting & Noakes 1995). Larger hind guts were associated with increased capacity of those organs that contribute the most to nutrient and energy extraction from a particular diet type.

The structure of the gastrointestinal tract (GI) is fairly homogeneous among different orders of mammals (Chivers & Hladik 1980), and the development of different parts of the GI generally reflect adaptations to different foods (Bruorton & Perrin 1991, W i l c z y n s k a 1998, 1999). V o r o n t s o v (1962) argued that the evolutionary transitional trends of gut morphology for rodent species indicated the changes from feeding on energy-dense but hard to get food, such as invertebrates and seeds, to less energy-dense but easier-to-get food in the form of the vegetative parts of plants. E l l i s et al. (1994) extended Vorontsov's hypothesis and stated that it could be predicted that diet and alimentary tract morphology are reflected by their life histories of animals. Species that eat high-energy foods and display digestive tract adaptations to a high quality diet will possess life-history traits similar to those of relatively opportunistic species such as high motional ability, high fecundity, and the ability to exploit temporarily ideal but relatively unstable habitats, whereas those with adaptations to a herbivorous diet should possess the converse life history traits. In our study, the only strict herbivore – *M. brandti* is diurnal and living in family groups. Their habitats are relative stable and, however, they have a relative high fecundity and high activities, which is not consistent with the prediction. For the other five species, *P. robovskii* is nocturnal, mainly feeding on plant seeds and invertebrates, but they live in relative stable habitat and have a relative low fecundity and activity. *S. daurica,* which is diurnal and mainly feeding on grass and plus a little insects, live in a relative stable habit and have relative high fecundity and high activity, which is in agreement with the prediction. *C. barabensis, C. triton,* and *Me. unguiculatus* have similar food habits to *P. robovskii.* They all have relative high fecundity and high activities, and *C. barabensis* lives in a relative stable habitats (not consist with prediction) whereas *C. triton* (nocturnal) and *Me. unguiculatus* (diurnal) live in relative unstable habitats (consist with the prediction).

In conclusion: 1) the strict herbivore, *M.brandti*, showed the longest large intestine and ceacum, which is consistent with our prediction; 2) the small intestine does not reflect the dietary fiber contents and thus not to be a good indicator for food habits; 3) hind gut is more important for herbivorous than for omnivorous rodents, and could be a relative reliable indicator for food habits; 4) it seems that there is no direct cause and effect relationship between some life history traits and gut morphology for rodent species in this study. It should be noted that the gut sizes of rodents change with season (food quality and temperature), reproductive status, and other internal and /or external factors. These conclusions are only limited to the summer season.

Appendix. The absolute mean measurements of digestive tract for six species of rodents (±SD).

Species	Stomach (cm) (cm)	Small intestine (cm)	Large intestine (cm)	Cecum (cm)	Total GI (cm)
Microtus brandti	2.5±0.4	25.7±2.7	21.7±2.3	12.1±1.7	62.0±5.2
Spermophilus daurica	5.1±0.5	78.3±6.5	24.7±3.2	8.2±1.3	116.3±9.2
Cricetulus triton	4.6±0.4	49.8±4.3	22.6±1.7	7.2±1.1	84.2±4.9
Cricetulus barabensis	3.2±0.5	32.0±5.7	12.6±1.4	5.6±0.5	53.4±5.8
Meriones unguiculatus	2.3±0.2	34.3±5.1	13.2±2.9	4.9±0.6	54.7±8.2
Phodopus robovskii	2.2±0.2	21.3±0.4	9.5±0.0	2.7±0.7	35.6±1.3

A c k n o w l e d g e m e n t s

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