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FOOD INTAKE, ASSIMILATION EFFICIENCY, AND GROWTH OF JUVENILE LIZARDS *TAKYDROMUS SEPTENTRIONALIS*

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Abstract—1. Juvenile *Takydromus septentrionalis* at 28, 30 and 32°C exhibited no significant differences in food intake but significant differences in weight-specific food intake, with the highest food intake (384.6 cal/day) and the highest weight-specific food intake (195.2 cal/g/day) occurring at 32 and at 30°C, respectively.

2. The assimilation efficiencies at 28, 30 and 32°C averaged 87.7, 88.7 and 83.3%, respectively.

3. No significant differences in growth were observed among lizards at different temperatures.

INTRODUCTION

Many aspects of biology and ecology in lizards are well known, but data available on food intake and assimilation efficiency has been limited. Such data is useful in determining the role of lizards in the energy dynamics of ecosystems (Ballinger and Holscher, 1983). Until recently, lizards, regarded as a primary carnivore, have been unsuitably considered to play a minor role in community energetics. The few previous studies have generally showed that the assimilation efficiency increases with body temperature for both herbivores (Harlow *et al.*, 1976) and insectivores (Harwood, 1979). Waldschmidt *et al.* (1986), however, concluded that body temperature influenced saurian assimilation primarily by affecting both the consumption and passage time of food while only slightly affecting the assimilation efficiency. Similarly, Ji and Wang (1990) showed that (1) the food intake of the wall lizard *Gekko japonicus* increased with body temperature; (2) the greatest assimilation efficiency of the wall lizard occurred at 23°C not at other lower or higher temperatures either in the breeding season or in the fall; (3) the assimilation efficiency of the wall lizard at any temperature in the fall was significantly greater than that at the correspondent temperature in the breeding season.

Takydromus septentrionalis studied here is a widely foraging diurnal insectivore. Lizards of 55 mm SVL (snout-vent length) or more are considered adults, because most are seen to lay eggs or to mate at this size (Liu, 1939; Wang, 1966). The purposes of the present study were to measure (1) the daily food intake, (2) the assimilation efficiency and (3) the growth rate of juvenile *T. septentrionalis* at three temperatures.

MATERIALS AND METHODS

This study was conducted in Hangzhou, China. A total of 24 juvenile *T. septentrionalis* were collected from a field on Xiushan Island (30°11′N, 122°9′E) in the Zhoushan Islands in mid-April, 1992. All of them were second-year juveniles; their wet body mass and SVL averaged 2.0 g (range, 1.1–3.3 g) and 48.6 mm (range 39.3–53.6 mm), respectively. Lizards were divided into three groups of which each group was placed in 28, 30 and 32°C constant temperature rooms, respectively. The fluorescent tubes and room lighting were on 12L:12D cycle; lights came on at 6.30 a.m. Each lizard was housed in a 19 × 12 × 19 cm glass cage, then weighed and measured. These measurements were recorded as initial wet body mass and SVL. Final wet body mass and SVL were recorded at the end of a 72 hr fast which terminated each test period. The test period at 28, 30 and 32°C was 31, 25 and 25 days, respectively.

All lizards were allowed to feed freely on mealworms (larvae of *Tenebrio molitor*) and to sip water from water-saturated absorbent cotton. Defecated materials from each lizard were collected daily between 9 p.m. and 10.30 p.m. All of the materials used for caloric determination were dried to constant mass in an oven at 65°C and dry mass was recorded. Ash uncorrected caloric values of mealworm and defecated material were determined with a JR-2800 adiabatic bomb calorimeter manufactured by Changsha Instruments Factory, China. The assimilation efficiency (AE) was calculated as:

$$AE = (I - D)/I \times 100 \quad (1)$$

where I = total calories ingested and D = total calories defecated.

Table 1. Food intake (cal/day) and weight-specific food intake (cal/g/day) of juvenile *T. septentrionalis*

T (°C)	*N*	Body wt (g)	Food intake			Weight-specific food intake		
			Mean	SE	Range	Mean	SE	Range
28	9	1.8	308.1	42.3	143.7–533.3	179.0	26.2	76.3–339.1
30	8	1.8	326.3	28.1	254.1–478.6	195.2	29.8	121.3–386.6
32	7	2.6	384.6	48.2	261.1–537.3	149.0	8.4	103.3–176.6

Table 2. Caloric value (cal/g dry mass) of defecated material of juvenile *T. septentrionalis*

T (°C)	*N*	Mean	SE	Range
28	9	3588.6	60.4	3493.5–3765.6
30	8	3528.2	40.6	3471.9–3607.0
32	7	3662.2	19.2	3643.1–3701.5

RESULTS

Mealworms fed to *T. septentrionalis* at the constant temperature of 28, 30 and 32°C were 63.7% water and had a mean ash uncorrected caloric value of 6059.8 cal/g dry mass.

There was a significant positive correlation within each thermal regime between food intake and body size ($P < 0.01$). No statistically significant differences in food intake occurred among lizards at different temperatures [$F(2,21) = 0.940$, $P > 0.05$], but there was an obvious increase in food intake from 308.1 cal/day at 28°C to 384.6 cal/day at 32°C. In contrast, there were significant differences in weight-specific food intake among lizards at different temperatures, with the highest weight-specific food intake occurring at 30°C (Table 1).

When the defecated material collected at different temperatures was evaluated calorimetrically, there were small differences in their caloric values [$F(2,21) = 1.720$, $P > 0.05$]. The caloric values of defecated material from 28, 30 and 32°C averaged 3588.6, 3528.2 and 3663.2 cal/g dry mass, respectively (Table 2). Lizards intaking 1.0 cal mealworm defecated averagely 0.13 cal at 28°C, 0.11 cal at 30°C and 0.17 cal at 32°C. There were significant differences in defecated material production among lizards at different temperatures [$F(2,21) = 4.112$, $P < 0.05$], with the highest defecated material production occurring at 32°C. No statistically significant differences in weight-specific defecated material production occurred among lizards at different temperatures [$F(2,21) = 0.877$, $P > 0.05$], but the lizards at 32°C also had the highest weight-specific defecated material production (Table 3).

Ambient temperature had a slight effect on the assimilation efficiency [$F(2,21) = 1.416$, $P > 0.05$]; the assimilation efficiency at 28, 30 and 32°C averaged 87.7, 88.7 and 83.3%, respectively (Table 4).

No significant differences in growth rates of both wet body mass [$F(2,21) = 0.977$, $P > 0.05$] and SVL [$F(2,21) = 1.475$, $P > 0.05$] occurred among lizards at different temperatures, but the lizards at 28°C had noticeably higher growth rates than those at 32°C (Table 5).

DISCUSSION

Higher food intake of the lizards at 32°C is primarily due to (1) lizards at higher temperatures have higher energy demands for somatic maintenance and (2) larger lizards generally exhibit higher food intake. The result that indicates weight-specific food intake does not increase with temperature is similar to that reported in the side-blotched lizard *Uta stansburiana*. Waldschmidt *et al.* (1986) reported that weight-specific food intake of *U. stansburiana* increases rapidly from 0.0 mg/g/day at 20°C to 50.0 mg/g/day at 28°C which was maintained up to 36°C. In contrast, Harwood (1979) showed that the western fence lizard *Sceloporus occidentalis*, the western whiptail lizards *Cnemidophorus tigris*, and the southern alligator lizard *Gerrhonotus multicarinatus* increased their weight-specific food intakes with increasing temperature until their body temperatures neared the upper lethal limit.

High assimilation efficiency (80%+) reported in this paper are consistent with those reported for other insectivorous lizards with assimilation efficiency generally varying from 70 to 95% (Andrews and Asato, 1977; Avery, 1971; Ballinger and Holscher, 1983; Dutton *et al.*, 1975; Essghaier and Johnson, 1975; Harwood, 1979; Ji and Wang, 1990; Kitchell and Windell, 1972; Mueller, 1970; Waldschmidt *et al.*, 1986). Two factors, mass of defecated material and its caloric value, are believed to play an important role in determining assimilation efficiency, because the

Table 3. Defecated material production (cal/day) and weight-specific defecated material production (cal/g/day) of juvenile *T. septentrionalis*

T (°C)	*N*	Defecated material production			Weight-specific defecated material production		
		Mean	SE	Range	Mean	SE	Range
28	9	40.2	7.9	8.5–84.6	21.8	3.5	7.1–36.1
30	8	36.3	4.2	26.2–56.7	20.8	2.1	12.1–28.1
32	7	64.1	8.5	35.2–90.2	27.2	4.8	10.7–44.1

Table 4. Assimilation efficiency (%) of juvenile *T. septentrionalis*

T (°C)	*N*	Mean	SE	Range
28	9	87.7	2.3	72.7–93.0
30	8	88.7	1.3	82.2–93.2
32	7	83.3	1.0	78.8–86.5

total defecated calories is a product of fecal mass and its calories. Any mechanism that increases the total defecated calories will certainly result in reduced efficiencies (Harwood, 1979). There are three possible patterns in which the two factors can be arranged to increase total defecated calories: (1) mass-specific caloric value remains unchanged while the mass of defecated material is increased (Harlow *et al.*, 1976); (2) both mass-specific caloric values and mass of defecated material increase (Harwood, 1979); and (3) defecated material production remains relatively unchanged but its caloric value increases (Kepenis and McManus, 1974). *T. septentrionalis* seem to belong to the second pattern.

Changes in assimilation efficiency with temperature involve the thermal sensitivity of enzyme systems, because the maximum enzyme activity is characteristically associated with an optimal temperature and pH (Harwood, 1979). Theoretically, the activity of digestive enzymes decreases as temperature decreases below or increases above a certain level. However, lizards at low temperatures might maintain relatively normal assimilation efficiencies by increasing food residency time which would prolong exposure of food to enzymatic action. *T. septentrionalis* seem to be able to maintain relatively constant assimilation efficiencies over a certain temperature range in this way. Waldschmidt *et al.* (1986) found that variations in temperature could greatly affect *Uta*'s consumption and passage time but had a much smaller effect on its assimilation efficiency. Similarly, Ji and Wang (1990) reported that ambient temperature had a significant effect on *G. japonicus*'s food intake but had only a slight effect on its assimilation efficiency.

Although we have no direct data from physiology and biochemistry, it is reasonable to conclude that the relatively lower assimilation efficiency at 32°C in juvenile *T. septentrionalis* may primarily result from decreased food residency time and/or decreased enzyme activity. The highest defecated material production and the highest weight-specific fecal caloric value strongly suggest that assimilation efficiency is impaired at 32°C.

The relative allocation of assimilated energy by juvenile *T. septentrionalis* can be evaluated by comparing respiration, production, faeces and urinary wastes. Given a certain amount of food, lizards with the lowest defecated calories and the lowest maintenance costs will have the highest growth rate.

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Table 5. Growth rates in wet body mass (g/day) and SVL (mm/day) of juvenile *T. septentrionalis*

T		Body mass			SVL		
(°C)	*N*	Mean	SE	Range	Mean	SE	Range
28	9	0.030	0.008	0.006–0.049	0.032	0.015	0.003–0.149
30	8	0.029	0.007	−0.003–0.041	0.015	0.002	0.002–0.023
32	7	0.016	0.007	−0.003–0.044	0.007	0.002	0.001–0.014