Comp. Biochem. Physiol. Vol. 96A, No. 2, pp. 267–271, 1990
Printed in Great Britain

0300-9629/90 $3.00 + 0.00

ANNUAL CYCLES OF LIPID CONTENTS AND CALORIC VALUES OF CARCASS AND SOME ORGANS OF THE GECKO, *GEKKO JAPONICUS*

JI XIANG* and WANG PEICHAO†
*Department of Biology, Hangzhou Normal College, Hangzhou 310012, Zhejiang Province, P.R.C.;
†Department of Biology, East China Normal University, Shanghai 200062, P.R.C.

(*Received* 27 *November* 1989)

Abstract—1. The primary sites where lipid storage and utilization occurred in the gecko *Gekko japonicus* were carcass and liver.

2. Annual cycles of lipid contents of the primary lipid reserves associated with winter hibernation and reproduction.

3. Seasonal changes in caloric values of carcass, lean carcass, liver and gastrointestinal tract were correlated with lipid contents of these parts and seasonal conditions of individuals.

4. Besides lipids, some other energy materials could be utilized for somatic maintenance during hibernation period.

INTRODUCTION

Reproductive demands and seasonal variation of food availability are the principal environmental determinants of seasonal conditions in most temperate reptiles. Many investigators have studied seasonal variations of fat bodies and/or lipid contents (Hahn and Tinkle, 1965; Avery, 1970; Derickson, 1974, 1976; Ballinger *et al.*, 1981; Droge *et al.*, 1982; Ballinger and Hipp, 1985; Loumbordis, 1987; Sceler, 1987; Abts, 1988; Cruz *et al.*, 1988), but studies of seasonal variations of caloric values of carcass and some organs in reptiles have been limited. Some of these investigators found that fat bodies and/or lipids were utilized for reproduction and/or somatic maintenance during the hibernation period. Most lizard species store lipids in abdominal fat bodies, carcass, liver and some other organs. There may be differential storage and utilization at different sites, depending on the life history of lizards (Hahn and Tinkle, 1965; Mueller, 1969). Derickson (1976) showed that there were four types of lipid storage and utilization patterns in lizards, including (1) no cycling, (2) cycling associated only with winter hibernation, (3) cycling associated with winter hibernation and reproduction, and (4) cycling associated only with reproduction. Cheng (1988), however, declcared that the lipid storage and utilization patterns of the three lizard species in Taiwan were different from any type of the Derickson's four patterns.

The aim of this study was to (1) identify the primary sites where lipids storage and utilization occurred in the gecko *G. japonicus*, a very common nocturnal species in Hangzhou, and (2) determine the annual cycles of lipid contents and caloric values of carcass and some organs of the gecko, and their relative importance to reproduction and hibernation.

MATERIALS AND METHODS

This study was conducted in Shanghai, China. Monthly samples of the gecko *G. japonicus* were collected during 1987–1988 on buildings in Hangzhou (30°16′N, 120°9′E), Zhejiang province. Only sexually matured individuals with snout-vent lengths larger than 56.0 mm were used in this investigation (Tokunaga, 1984).

The collected geckos were weighed and autopsied in the laboratory. Carcass (including tail), liver and gastrointestinal tract were separated and weighed respectively. All of these potential energy reserve parts were dried to constant weight in an oven at 65°C and dry weight was obtained. Size and mass of follicles, yolked follicles, oviductal eggs and testes were noted. Carcasses and livers were ground in an electric mill, caloric values, including carcass, lean carcass (lipids were extracted), liver and gastrointestinal tract, were determined with a LR-2800 adiabatic bomb calorimeter manufactured by Changsha Instruments Factory. Ash was defined as residue remaining after combustion in the bomb calorimeter.

Lipids stored in carcass and liver were extracted in Soxhlex apparatus at 55°C for 5.5 hr, absolute ether was used as solvent. After the extraction, the samples were dried in an oven at 65°C and weighed. The lipid contents were calculated as (extracted lipid mass/sample dry mass × 100). Lipids stored in liver were determined in three important stages during a year, i.e. peak vitellogenesis period, entrance to and emergence from hibernation.

RESULTS

The gecko *G. japonicus* has no visible fat bodies, and most lipids are stored in carcass, especially in posterior parts of carcass, these parts include areas around posterior legs and tail. Liver is another important lipid reserve, which can store considerable amounts of lipid. Prior to hibernation, *G. japonicus* has accumulated great amounts of lipids in these lipids reserves.

Carcass

There was no significant difference in lipid contents ($X^2 = 0.4161$, $P > 0.05$), ash-free caloric values ($X^2 = 2.7432$, $P > 0.05$) and ash uncorrected caloric values ($X^2 = 3.4005$, $P > 0.05$) of carcasses between males and females. There was also no significant difference in ash-free caloric values ($X^2 = 0.0085$, $P > 0.05$) and ash uncorrected caloric values ($X^2 = 1.2464, P > 0.05$) of lean carcasses between males and females. Although no significant monthly changes in lipid contents of carcasses occurred in an annual cycle [$F(10,190) = 1.4081, P > 0.05$], the lipid contents of males and females were identical with a peak in late November. Lipids stored at this site lost considerable mass during the hibernation period. The lowest amounts of lipids were recorded in late March, when the gecko emerged from hibernation (Fig. 1). No apparent correlation existed between testicular and ovarian activity and the lipid contents of males and females, although a decline was observed in early May, when active courtship, mating and maximum vitellogenesis activity occurred.

Significant monthly changes in ash-free caloric values [$F(9,138) = 5.8286, P < 0.01$] and ash uncorrected caloric values [$F(9,138) = 4.7740, P < 0.01$] of carcasses occurred in an annual cycle. Ash-free caloric values [$F(9,131) = 11.8987, P < 0.01$] and ash uncorrected caloric values [$F(9,132) = 2.2723$, $P < 0.05$] of lean carcasses were similar to those of carcasses (Fig. 2). The maximal caloric values of carcass occurred in late November, the value declined during the hibernation period, and reached a minimum in March. After emergence from hibernation, the caloric value increased, but remained at a relatively lower level than those during reproduction period (from late May to early August). The lowest caloric value of lean carcass occurred in late period of hibernation, whilst there was no significant difference between other months.

Organs

Females had significantly higher lipid contents of livers than those of males' ($X^2 = 4.5074, P < 0.05$). The data of males were excluded from this paper, for the reason of their irregular monthly changes in this study. Ash uncorrected caloric values of females' livers were significantly greater than those of males' ($X^2 = 25.6097, P < 0.01$). There was no significant difference in ash uncorrected caloric values of gastrointestinal tracts between males and females ($X^2 = 0.0046, P > 0.05$). Lipid contents of females' livers at the beginning of hibernation (15 Dec.) were significantly higher than those in late period of hibernation (31 Mar.) ($t = 3.2109, P < 0.01$, d.f. = 17) and those in the peak vitellogenesis (20 Apr.–5 May) ($t = 2.9920, P < 0.01$, d.f. = 19). Lipid contents of females' livers were similar both in late period of hibernation and in the period of vitellogenesis ($t = 0.5184, P > 0.05$, d.f. = 12) (Table 1).

Although no significant monthly changes in ash uncorrected caloric values of females' livers occurred in an annual cycle [$F(9,67) = 0.3956, P > 0.05$] (Fig. 3), the values were relatively greater in late November, declined during hibernation period, and increased after emergence from hibernation. These changes were similar to those of lipid contents of livers. In contrast to females, there were significant monthly changes in ash uncorrected caloric values of males' livers, but the caloric values changed irregularly, and had a remarkably higher value in early August, when the gecko was in its late period of reproduction (Fig. 3).

Significant monthly changes also occurred in ash uncorrected caloric values of gastrointestinal tracts [$F(9,132) = 11.8322, P < 0.01$], the caloric values appeared to associate only with hibernation, the maximum value occurred in late November, while decreased rapidly during hibernation period (Fig. 4).

DISCUSSION

G. japonicus exhibit significant seasonal changes of lipid contents of carcass and liver. These parts of the gecko's body are the primary lipid reserves. Lipids stored at these sites can be utilized for somantic maintenance during hibernation period and partially for the demands of reproduction. Peak period of lipid storage occurred well before late November, when hibernation begins. This pattern is similar to that observed in most temperate reptiles, and appears to belong to Derickson's type 3, since the gecko utilizes considerable amounts of lipids during hibernation period and in the early period of reproduction (from late May to early June).

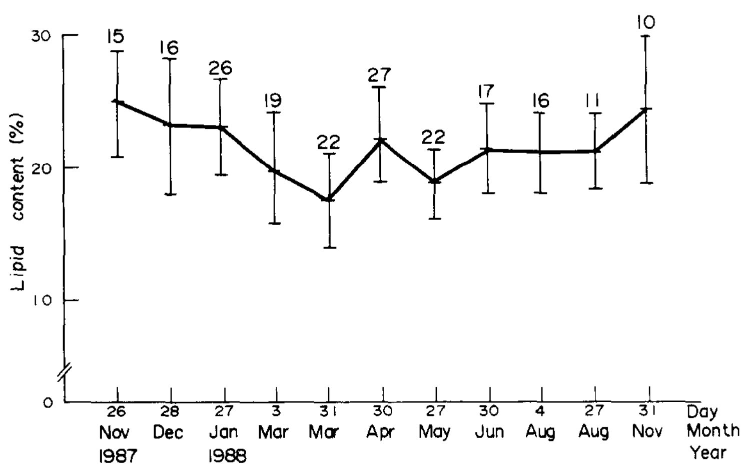

Fig. 1. Monthly changes in lipid content of carcass of the gecko *G. japonicus*. Mean ± 2SE, sample size (number of geckos) as indicated in the figure.

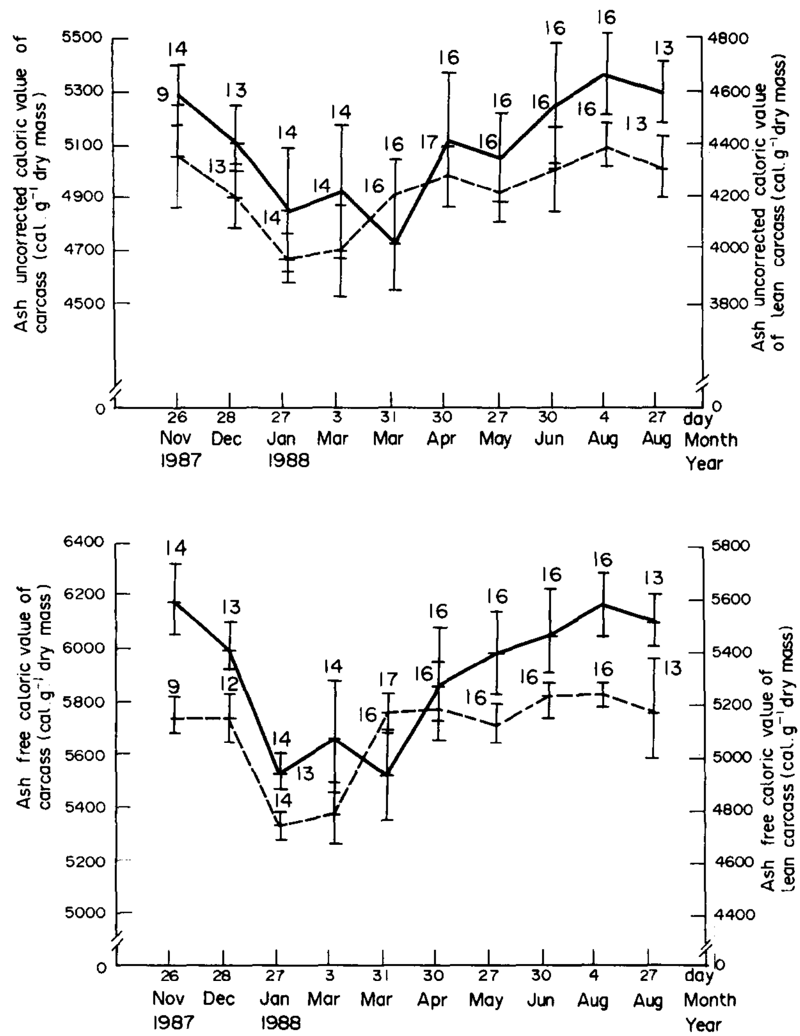

Fig. 2. Annual cycles of caloric values of carcass (——) and lean carcass (----) of the gecko *G. japonicus*. Mean ± 2SE, sample size as indicated in the figure.

Several kinds of external and internal factors, e.g. photoperiod, ambient temperature, food availability, courtship, mating, sperm and egg development are believed to play an important role in determining lipid storage and utilization patterns of lizards (Litch, 1966, 1967a, 1967b; Gorman and Litch, 1975; Ferrell and Meier, 1981; Ballinger and Hipp, 1985; Ballinger *et al.*, 1981). In Hangzhou, ambient temperature and food availability appear to exert a strong influence on the annual changes of lipid contents of carcass and liver of the gecko. The gecko refused to take food when the temperature was below 13°C (Ji and Wang, in press), the temperature would coincide with that of late November, when the gecko entered hibernation. Another relatively lower lipid level of carcass occurred in May, which would associate with the period of maximum vitellogenesis. After 27 May, 1988, lipid reserves increased steadily, this would be due to the relatively higher food availability.

Table 1. Lipid contents of females' livers measured in 15 Dec. 1987, 31 Mar. 1988 and 20 Apr.–5 May 1988. Mean ± 2SE and range, number of determinations in parentheses

15 Dec.	31 Mar.	20 Apr.–5 May
63.0 ± 6.0 (13)	45.2 ± 9.9 (6)	48.4 ± 7.7 (8)
31.7–73.5	25.0–58.0	24.2–57.4

Seasonal changes in caloric values of carcass, lean carcass, liver and gastrointestinal tract were correlated with lipid contents and seasonal conditions of individuals. Maximum caloric values occurred in those having the highest level of lipid contents in their carcass and some organs and in those in the best conditions. Seasonal changes in caloric values of lean carcass appeared to associate only with hibernation. From this phenomenon, we can conclude that *G. japonicus* utilized not only lipids stored in the carcass, but also other energy materials stored at this site of the body for somatic maintenance during hibernation period, while the relative importance to reproduction of these materials are not as obvious as lipids, the latter are a very important energy source, which *G. japonicus* can utilize for somatic maintenance during hibernation period and for reproduction. In contrast to the caloric value of the carcass, the caloric values of liver and gastrointestinal tract appear to associate only with hibernation, the relatively greater caloric

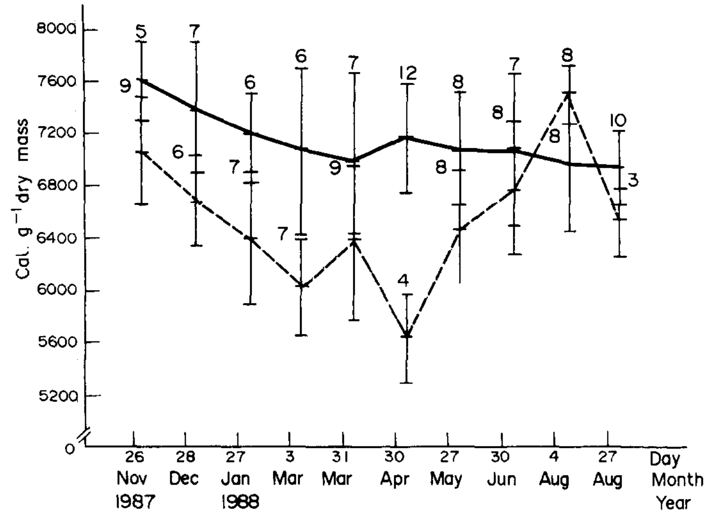

Fig. 3. Monthly changes in ash uncorrected caloric value of the gecko's liver. Mean ± 2SE, sample size as indicated in the figure. Females = ——, males = - - - -.

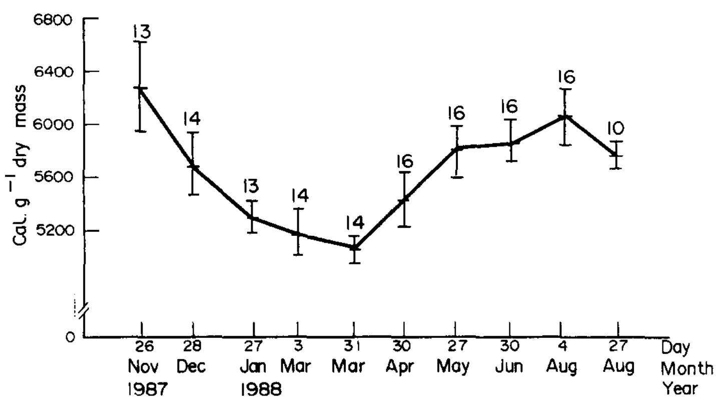

Fig. 4. Monthly changes in ash uncorrected caloric value of gastrointestinal tract. Mean ± 2SE, sample size as indicated in the figure.

values in other seasons are due to active metabolism during the period of reproduction, recrudescence and decrudescence of gonads. *G. japonicus* takes enough food in these periods to store excess assimilated materials in these organs.

In summary, food availability and reproductive demands are the two ultimate factors that determine the seasonal changes of lipid contents and caloric values of carcass and some organs of the gecko *G. japonicus*. Lipids stored in the gecko's body are strongly limited by reproductive demands and food shortage and by failing to take food at low temperature during hibernation period. Many investigators have obtained similar results observed in this study (Litch, 1974; Derickson, 1976; Rose, 1982). Most temperature reptiles store energy materials after hibernation, others store these materials both after hibernation and after maximum reproductive activity.

Acknowledgements—I would like to express my thanks to all the staff of the Animal Ecology Program of East China Normal University and to Mr. Zhao Shi who provided assistance with acquisition and maintenance of experimental apparatus. I would also like to thank Professors J. D. Congdon, R. E. Ballinger and R. M. Andrews for providing some literature. This work was supported in part by Scientific Fund of State Educational Committee.

REFERENCES

Abts M. L. (1988) Reproduction in Saxicolous desert *Sauromalus obesus*: The female reproductive cycle. *Copeia* **1988,** 382–393.

Avery R. A. (1970) Utilization of caudal fat by hibernating lizard *Lacerta vivipara*. *Comp. Biochem. Physiol.* **37A,** 119–121.

Ballinger R. E., Groge D. L. and Jones S. M. (1981) Reproduction in Nebraska sandhills population of the Northern prairie lizard *Sceloporus undulatus garmani*. *The American Midland Naturalist* **106,** 157–164.

Ballinger R. E. and Hipp T. G. (1985) Reproduction in the collared *Cortaphytus collaris* in west central Texas. *Copeia* **1985,** 976–980.

Cheng H. Y. (1988) A review on annual reproductive and energetic patterns of five taxa of lizards in Taiwan for ten years. *Proc. Natl. Sci., B.R.O.C.* **11,** 311–321.

Cruz F. R. M., Guillette L. J. Jr., Cruz M. V. S. and Gustavo Casas-Andreu (1988) Reproductive and fat body cycles of the viviparous lizard, *Sceloporus mucronatus* (*Sauria: Iguanidae*). *J. Herpetol.* **22,** 1–12.

Derickson W. K. (1974) Lipid desposition and utilization in the Sagebrush lizard, *Sceloporus graciosus*: Its significance for reproduction and maintenance. *Comp. Biochem. Physiol.* **49A,** 267–272.

Derickson W. K. (1976) Lipid storage and utilization in reptiles. *Amer. Zool.* **16,** 711–723.

Droge D. L., Jones S. M. and Ballinger R. E. (1982) Reproduction of *Holbrookia maculata* in Western Nebraska. *Copeia* **1982,** 356–362.

Ferrel B. R. and Meier A. H. (1981) Photo-thermoperiodic effects on fat stores in the green anole, *Anolis carolinensis. J. Exp. Zool.* **217,** 353–359.

Gorman B. R. and Litch P. (1975) Difference between the reproductive cycles of sumpatric lizards on Trinidad. *Copeia* **1975,** 352–357.

Hahn W. E. and Tinkle D. W. (1965) Fat body cycling and experimental evidence for its adaptive significance to ovarian follicles development in the lizard *Uta stansburiana. J. Exp. Zool.* **158,** 79–86.

Ji X. and Wang P. C. (1989) The effect of temperature on food intake and assimilation coefficiency of the gecko *Gekko japonicus. Journal of Hangzhou Normal College.* In press.

Klekowski R. Z. (1975) Physiological approach to ecological energetics. In IBP Handboodk No. 24 (*Methods for Ecological Bioenergetics*). (Edited by Grodzinski W., Klekowski R. Z. and Duncan A.), pp. 15–50. Blackwell Scientific Publication, Oxford.

Litch P. (1967a) Environmental control of annual testicular cycles in the lizard *Anolis carolinensis* I. Interaction of light and temperature in the initiation of testicular recrudescence. *J. Exp. Zool.* **165,** 505–516.

Litch P. (1967b) Environmental control of annual testicular cycles in the lizard *Anolis carolinensis* II. Seasonal variations in the effects of photoperiod and temperature on testicular recrudescence. *J. Exp. Zool.* **166,** 243–254.

Litch P. (1974) Response of *Anolis* lizard to food supplementation in nature. *Copeia* **1974,** 215–221.

Loumbordis N. S. (1987) Lipid storage and utilization in the lizard *Agama stellio stellio. J. Herpetol.* **21,** 237–239.

Mueller C. F. (1969) Temperature and energy characteristics of the sagebrush lizard (*Sceloporus graciosus*) in Yellowstone National Park. *Copeia* **1969,** 153–160.

Rose B. (1982) Food intake and reproduction in *Anolis acutus. Copeia* **1982,** 330–332.

Scelcer K. W. (1987) Seasonal variation in fat body and liver mass of the introduced Mediterranean gecko *Hemidatylus turcious*, in Texas. *J. Herpetol.* **21,** 74–78.

Smith G. C. (1976) Ecology energetics of three species of ectothermic vertebrates. *Ecology* **57,** 252–264.

Tokunaga S. (1984) Morphological variation and sexual dimorphism in *Gekko japonicus* from Fukuoka, Northern Kyushu, Japan. *Jap. J. Herpetol.* **10,** 80–88.