

Energy consumption in non-reproducing adults of the eastern hedgehog *Erinaceus concolor*

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Energy balance and body mass changes were studied in non-reproducing adult eastern hedgehogs *Erinaceus concolor* (Martin, 1838) during an 8-day feeding trial. The amount of energy consumed by the hedgehogs that maintained constant body mass averaged $0.74 \text{ kJ} \times \text{g}^{-1} \times \text{day}^{-1}$. The energy equivalent of body mass loss amounted to $15.12 \text{ kJ} \times \text{g}^{-1}$, and that of body mass gain was 25.18 kJ energy consumed $\times \text{g}^{-1}$. If the energy contents of body mass gained and lost were the same, biomass production efficiency was 72.2%.

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Introduction

Hedgehogs of the genus *Erinaceus* share characteristics that have been interpreted as energy-saving strategies. These include a nocturnal niche (Crompton *et al.* 1978), using spines to reduce predation (McNab 1986), the ability to enter torpor during the whole active season (Fowler 1988), and long hibernation (Dmi'el and Schwarz 1984). However, the hedgehog's energetics, especially the economics of energy allocation, is relatively little known. There is only scattered data on their metabolic rates, regarding the European hedgehog *E. europaeus* (e.g. Hildwein and Malan 1970, Shkolnik and Schmidt-Nielsen 1976, Tähti 1978, McNab 1980). The energetics of the two remaining species of *Erinaceus* apparently has never been studied.

The eastern hedgehog *Erinaceus concolor* (Martin, 1838) is a sibling species of *E. europaeus*, inhabiting a range extending from Eastern Europe (about 14°E) to the River Ob (about 80°E), north to about 60°N in Russia and West Siberia, and south to Israel and Northern Iran (Corbet 1988, Frost *et al.* 1991). This paper, which is part of a larger study on the total energy budget of the eastern hedgehog

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(Król 1992), reports on the energy requirements of non-reproducing adults, as measured by the food balance method.

Material and methods

Hedgehogs were captured in Cracow (50°N, 20°E) in the spring of 1989. The animals, housed outdoors, were exposed to natural photoperiods and temperature, and fed and watered *ad libitum*. Five adult, non-reproducing individuals (3 females and 2 males) were used for this experiment. Four days before the experimental trial, the hedgehogs were put on a homogenous diet of cooked horsemeat, cornflakes and carrots in weight proportions of 20:1:1. This food contained 59.6% water and 26.53 kJ energy per gram dry mass.

The experiment was conducted in June and lasted 8 days. The animals were placed in pens (2 × 3 × 1 m each) lined with polyethylene sheeting and covered with wire netting (1 cm mesh), which allowed collection of the uneaten food and faeces. Wooden nest boxes (90 × 70 × 60 cm) were provided in the pens. Every day between 19.30 and 20.30 the animals were weighed, uneaten food and faeces were collected, and fresh food was supplied in excess. The uneaten food and faeces were oven-dried at 105°C and weighed, and samples were combusted in an adiabatic bomb calorimeter KL-3 ("Precyzja", Bydgoszcz) (Górecki 1975). This procedure allowed estimation of energy consumption (C), energy losses in faeces (F), and digestibility coefficient ($(C - F)/C$) (Drożdż 1975). The values of C and F are expressed in kJ per unit of time.

Relationship between energy consumption and body mass changes was described by reduced major axis equations (Sokal and Rohlf 1981). In these equations (general form: $Y = a + v_{y \cdot x}X$), the correlation coefficient (r) and standard error of the slope (s_v) are also given; n refers to the number of measurements taken and N to the number of individuals used. Means are reported \pm SD. Differences between means were tested by one-way ANOVA (Sokal and Rohlf 1981).

Results

During the 8-day feeding trial the hedgehogs had considerable daily body mass changes (ΔM , range -36.5 to $+40.5$ g \times day $^{-1}$) and different levels of daily energy consumption (C , range 121.2 to 1596.8 kJ \times day $^{-1}$). These values were highly correlated, according to the reduced major axis equations fitted separately to energy consumption corresponding to negative and positive body mass changes (Fig. 1):

for $DM < 0$

$$C = 647.37 + 15.12 \Delta M \quad (n = 16, N = 5, r = 0.98, s_v = 0.88), \quad (1)$$

for $DM > 0$

$$C = 520.82 + 25.18 \Delta M \quad (n = 24, N = 5, r = 0.93, s_v = 2.12). \quad (2)$$

The slope coefficients of these lines, which may be regarded as energy equivalents of body mass changes, show that burning 1 g of the animal's own tissues yielded 15.12 kJ energy (equation 1), whereas deposition of 1 g of body tissue required additional energy consumption of 25.18 kJ (equation 2). The hedgehogs that maintained constant body mass ($\Delta M \cong 0$, range -1.6 to $+0.6$ g \times day $^{-1}$) consumed 0.74 ± 0.03 kJ \times g $^{-1}$ \times day $^{-1}$ ($n = 4, N = 3$).

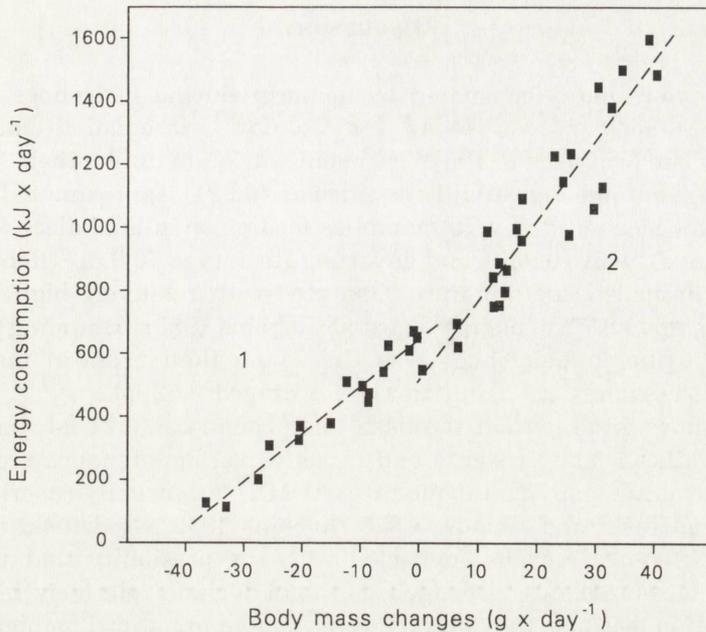


Fig. 1. Correlation between daily energy consumption (C) and daily body mass changes (ΔM) in 5 eastern hedgehogs during an 8-day feeding trial. The equations for lines 1 and 2 are given in the text.

The caloric values of the faeces did not differ statistically between individuals ($p > 0.05$, ANOVA), and averaged $20.58 \pm 1.49 \text{ kJ} \times \text{g}^{-1}$ dry mass ($n = 40$, $N = 5$). The digestibility coefficient amounted to 0.921 ± 0.005 ($n = 5$, $N = 5$) (Table 1).

Table 1. Energy consumption, energy loss in faeces and digestibility coefficient in 5 eastern hedgehogs during an 8-day feeding trial.

Animal		Initial	Final	Energy	Energy loss	Digestibility
No	Sex	body	body	consumption	in faeces	coefficient
		mass	mass	C	F	$(C - F)/C$
		(g)	(g)	(kJ/8 days)	(kJ/8 days)	(kJ/8 days)
1	F	728.5	765.0	4936.2	394.9	0.920
2	M	783.0	834.1	5391.2	404.3	0.925
3	F	782.5	865.0	6688.6	508.3	0.924
4	F	840.2	888.7	5674.5	499.4	0.912
5	M	842.6	917.5	5781.7	445.2	0.923
Mean				5694.4	450.4	0.921
SD				644.8	52.4	0.005

Discussion

The amount of energy consumed by non-reproducing hedgehogs that maintained constant body mass ($0.74 \text{ kJ} \times \text{g}^{-1} \times \text{day}^{-1}$) is equal to their costs of maintenance. The food used in the experiment was quite unlike their natural diet (invertebrates), but its digestibility coefficient (0.921) approximated the corresponding values measured in wild mammals feeding on animal diets of mammals and birds (0.894), fish (0.939) and invertebrate larvae (0.912) (Robbins 1983). High-protein animal-tissue diets are connected with relatively high energy loss through urine, up to 9.7% of energy digested (Robbins 1983). Assuming that energy loss through urine in hedgehogs was the same, their costs of maintenance, expressed as the energy assimilation rate, averaged $0.62 \text{ kJ} \times \text{g}^{-1} \times \text{day}^{-1}$. This value is 2.9 times greater than the basal metabolic rate ($0.21 \text{ kJ} \times \text{g}^{-1} \times \text{day}^{-1}$; Król 1994), while in many rodents and insectivores, maintenance requirements, expressed as average daily metabolic rate (ADMR), are usually reported as twice BMR (e.g. Grodziński and Wunder 1975, Robbins 1983, Grodziński and Weiner 1984). This difference may be connected with the possibility that the costs of maintenance measured in the hedgehogs might include relatively high costs of thermoregulation, because the animals were exposed to natural ambient temperatures ranging from 9.2 to 25.1°C, with a daily average of 16.4°C (Król 1992). Most ADMR measurements published so far have been taken at constant ambient temperature of 20°C (e.g. Grodziński and Wunder 1975, French *et al.* 1976).

The energy content of body mass loss amounted to $15.12 \text{ kJ} \times \text{g}^{-1}$ (equation 1). Since anhydrous body protein and fat in wild mammals comprise on average 22.72 and $38.12 \text{ kJ} \times \text{g}^{-1}$, respectively (Robbins 1983), and hydration of protein tissues is about 7 times that of adipose tissue where fat is stored (Groscolas 1988), it may be assumed that body mass loss observed in the present experiment was based on depletion of body fat reserves. The energy content of body mass loss in hedgehogs ($15.12 \text{ kJ} \times \text{g}^{-1}$) was similar to that reported for birds, *Fringilla coelebs* ($12.17 - 20.33 \text{ kJ} \times \text{g}^{-1}$, Dolnik 1968) and *Streptopelia risoria* ($16.32 \text{ kJ} \times \text{g}^{-1}$, Brisbin 1969); and for rodents, *Sigmodon hispidus* ($14.6 \text{ kJ} \times \text{g}^{-1}$, Randolph *et al.* 1977), *Microtus arvalis* ($23.36 \text{ kJ} \times \text{g}^{-1}$, Jagosz *et al.* 1979) and *Phodopus sungorus* ($19.3 \text{ kJ} \times \text{g}^{-1}$, Weiner 1987).

The energy equivalent of body mass gain was $25.18 \text{ kJ energy consumed} \times \text{g}^{-1}$ (equation 2), which after subtracting the energy value of faeces and urine corresponded to $20.95 \text{ kJ energy assimilated} \times \text{g}^{-1}$. The corresponding values reported for *Microtus arvalis* and *Rattus norvegicus* are $35.86 \text{ kJ energy assimilated} \times \text{g}^{-1}$ (Jagosz *et al.* 1979) and $13-20 \text{ kJ energy assimilated} \times \text{g}^{-1}$ (Farrell and Williams 1989), respectively. The differences between these values probably depend on the composition of body mass gain, but neither study investigated it. On the other hand, it is known that deposition of 1 kJ protein and 1 kJ fat require on average 2.06 and 1.37 kJ assimilated energy, respectively (see Pullar and Webster 1977 for review). This means that the energy efficiency of protein

deposition amounts to 48.5% ($1 \text{ kJ}/2.06 \text{ kJ} \times 100$), while that of fat deposition amounts to 73.0% ($1 \text{ kJ}/1.37 \text{ kJ} \times 100$). In the hedgehogs, assuming that the energy contents of body mass gain and body mass loss were the same, biomass production efficiency was 72.2% ($15.12 \text{ kJ}/20.95 \text{ kJ} \times 100$), suggesting deposition of fat tissue.

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