EFFECT OF TEMPERATURE AND BODY SIZE ON THE METABOLIC RATE OF THE EGYPTIAN HOUSE MICE *MUS MUSCULUS* AND THE ROOF *RAT RATTUS* RATTUS

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SUMMARY: The metabolic rate of the different sized rodents in relation to external temperature was studied. These rodents are the house mice Mus musculus and the roof rat Rattus rattus inhabiting the houses and fields of Egypt. The results show that the mice Mus musculus of small size had a higher rate of oxygen consumption and higher heat production than the large size one Rattus rattus. Also, the data indicate that increase of external temperature resulted in a significant decrease of oxygen consumption in the two experimental species up to 30ºC, then a gradual increase in oxygen consumption takes place as temperature increases. However, the zone of thermal neutrality and basal metabolism lies around 30ºC. From the metabolic rates obtained at various ambient temperatures, a temperature- metabolism curve can be constructed in the two experimental species.

Key words: Metabolic rate, mus musculus, rattus rattus.

INTRODUCTION

Respiratory exchange provides a convenient measure of energy utilization of an animal and the rate of oxygen consumption reflects the metabolic activity of all aerobic organisms. The relationship of energy metabolism to temperature and body size has been considered in a variety of animals (2, 21-23, 29).

Birds and mammals have higher metabolic rates than fishes, amphibians and reptiles. This is partly because of higher body temperature of the homoeothermic group in which the oxygen consumption per unit weight increases inversely with the body weight. This may be attributed to the combined effects of the amount of active protoplasmic tissue (3), and the relatively greater heat loss from the smaller animals (14).

The relation between body size and metabolic rate had been extensively reviewed by Hemmingsen (12), White ford and Victor (27), Gans and Pough (10) and Kayed *et al.* (16). The tendency of variation of the energy rate with some fractional power of body weight has been also reviewed (7,17).

Previous studies also have established that body temperature was an important factor influencing metabolism in various organisms (5,13).

Kirmiz (13) investigated the energy metabolism in relation to external temperatures from 0 to 45ºC, for both the desert jerboa *Jaculus orientalis* and the Wistar rat. He found that the basal metabolism of jerboa was inferior to that of rat inspite of its small size. When the external temperature fell to 0ºC, the metabolism of the jerboa rose to the level of that of the rat. When the ambient temperature exceeded the thermo-neutral zone, the respiratory exchanges increased by 76% for the rat, 60% for the jerboa fed on dry diet.

It has been shown by McNab and Morrison (20) that population of rodent *Peromyscus sp.* has basal rates of metabolism lower by 20 to 30% than those of the mesic population. Semi desert population has an intermediate basal rate of metabolism. Other desert rodents also have basal rates of metabolism (11,18).

Hussein *et al.* (15) determined the oxygen consumption in relation to external temperature in three rodents inhabiting three different habitats. These rodents are the grass rat *Arvicanthis niloticus*, the semi desert rat *Nesokia indicia* and desert rat *Dipodillus amoenus*. They oncluded that at external temperatures below thermal neutrality (zone of heat production), the oxygen consumption level of *Nesokia* is lower than that of *Arvicanthis*, while that of *Dipodilus* is at an intermediate level.

However, there is a little work was done on the Egyptian mammals, especially that on rodents and no pub-

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lished studies of the influence of temperature on the metabolism of the house mice *Mus musculus* and roof rat *Rattus rattus* which are widely distributed in Egypt. Therefore, the aim of this study is to investigate the change in oxygen consumption at different external temperatures and body sizes. Also, the metabolic rate of the present species are compared with published information for other rodents from different climatic regions.

In addition, the metabolic rates obtained at various ambient temperatures can be used to construct a temperature metabolism curve and to estimate the cost of thermoregulation in experimental species.

MATERIALS AND METHODS

The rodents under study were collected by using the common wire traps. The traps were baited and distributed daily in some houses and fields of Abbis region, east of Alexandria, Egypt. The positive traps were collected daily and the trapped rodents were classified to species according to Anderson and Jones (1).

Ten individuals from each species were collected, weighed and individually caged in a metal test cage measuring 40x25x20 cm, for at least 7 days before any experimental measurements were made. The rodents were acclimated to laboratory conditions by placed in a constant- temperature room (25±1ºC). The animals fed daily on wheat and crushed corn and a 250 Watt reflector lamp was turned on automatically for 12 h per day which permite normal ecological conditions of light, food and temperature.

The resting metabolic rate (RMR) of the different size species was measured in terms of resting oxygen consumption rate (ccm/g/h) at different temperatures from 10 to 40ºC, using a closed-system manometric respirometer which was constructed by Skvortsov (24) as shown in Figure 1.

The apparatus operates on the following principle: oxygen is consumed by the animal and the expired carbon dioxide is immediately absorbed. The decrease in gas pressure causes oxygen to be drawn from the container (b) into the animal chamber (a). Then an equal amount of water flows from the burette (c) into the container through the water-type pressure valve (d) to replace the oxygen. Oxygen consumption can be read from the water level in the burette. During the experimental period the pressure inside the respirometer is slightly lower than the atmospheric pressure.

The animal is put into a small wire-mesh cage (e) to restrict its movements. The animal chamber and oxygen container are placed into a constant temperature water bath held within ±1.0ºC of the desired level. A period of at least 20 to 30 minutes should be allowed for the animal to adapt to its new environment before readings are taken.

The total volume of oxygen consumed by the animal during a run can be calculated from the difference between the initial and final readings of the water level in the burette taken over 30 or 60 minute period of time. The volume of oxygen per hour has to be adjusted to standard temperature and pressure (0ºC and 760 mmHg) by calculating it from the formula:

$$\text{Vstp.} = \frac{(\text{B-W})\ \text{T V}}{760\ \text{mm of Hg.}\ 273\ \text{C}} \text{ where}$$

$V_{stp.}$= the volume of oxygen (ccm) consumed at standard temperature and pressure.

B= barometric pressure in mm of Hg.

W= vapour pressure.

T= ambient temperature in C.

V= difference in the water level (ccm) in the burette at the beginning and end of experiment.

The corrected volume ($V_{stp.}$) divided by the weight of the animal gives the amount of oxygen consumed per unit body weight per hour (ccm 0.2/g/h). In order to express the metabo-

Table 1: Mean resting oxygen consumption values of the Mus musculus and rat Rattus rattus at different temperatures.

Mus Musculus				Rattus rattus		
Temperature (ºC)	No. of animals	Body weight (g) Mean±S.E.	Oxygen consumption (com/g/h) Mean±S.E.	No. of animals	Body weight (g) Mean±S.E.	Oxygen consumption (com/g/h) Mean±S.E.
10	10	16.50±2.66	3.16±1.03	10	124.13±3.69	2.97±1.14
15	10	123.92±3.38	2.15±1.35	10	16.33±3.01	2.34±1.37
20	10	15.40±2.92	1.93±1.05	9	121.31±3.78	1.72±1.19
25	9	16.00±3.12	1.49±1.04	9	117.64±3.66	1.39±1.08
30	8	14.68±3.08	0.98±1.12	9	118.44±290	0.74±1.17
35	8	15.50±2.67	1.54±1.51	8	116.50±3.44	1.14±1.04
40	8	13.90±4.16	2.11±1.15	8	118.35±4.44	1.84±1.19
Mean body weight		:	15.47±3.09	120.04±3.61		
Mean oxygen consumption		:				
Observed		:	1.94±1.18	1.70±1.16		
Estimated		:	1.71	1.91		
Observed/Estimated (%)		:	113.45	89.01		
Metabolism (Kcal/g/h)		:	9.31	8.16		

lism in terms of calories per gram per hour (kcal/g/h), it is sufficient to multiply the former value by 4.8, assuming that the respiratory quotient (RQ)=0.82, and the caloric value of 1 litter of oxygen as equal to 4.8 kcal (12).

Comparisons between the oxygen consumption rates of the different sized experimental species were made statistically by using the analysis of variance (ANOVA). The rejection level of statistical significance adapted was p>0.05 (25).

RESULTS

The resting metabolic rate (RMR) at body temperatures between 10 to 40°C was measured in two different sized rodents, the house mice *Mus musculus* (12.0-19.6 g) and the roof rat *Rattus rattus* (108.2-132.9 g). From the data presented in Table 1 and Figure 2, it is clear that the basal metabolism takes place between 25 and 30°C for the two species.

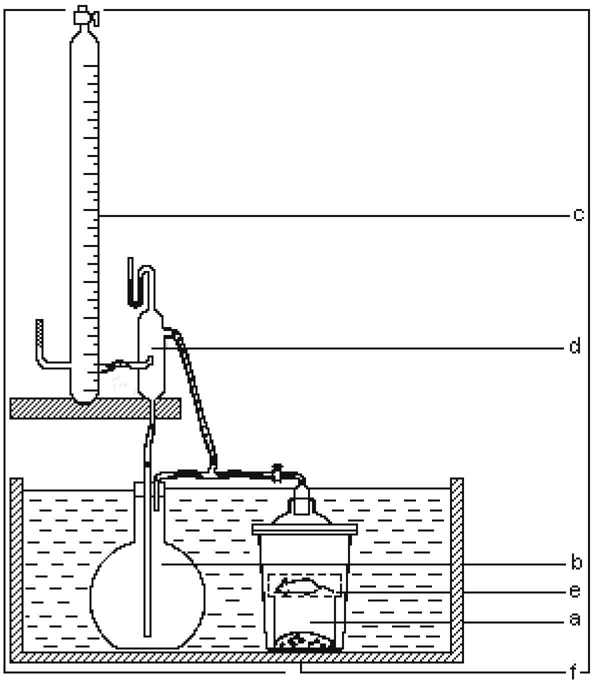

Figure 1: Diagram showing the structure of respirometer: a) glass desiccator-animal chamber; b) oxygen container; c) calibrated burette; d) water type pressure valve with manometer; e) wiremesh cage; f) carbon dioxide absorber (modified from Skvortsov, 1957).

The relationship of energy metabolism to size was applied according to Brody (7) as: $QO_2 = a W^b$ (where QO_2 is the oxygen uptake per hour per unit of body weight, W is the body mass, a and b are fitted constants equals 3.8 and -0.27 respectively). From this equation, the estimated oxygen consumption for *Mus musculus* was 1.71 when the mean body weight was 15.47 g

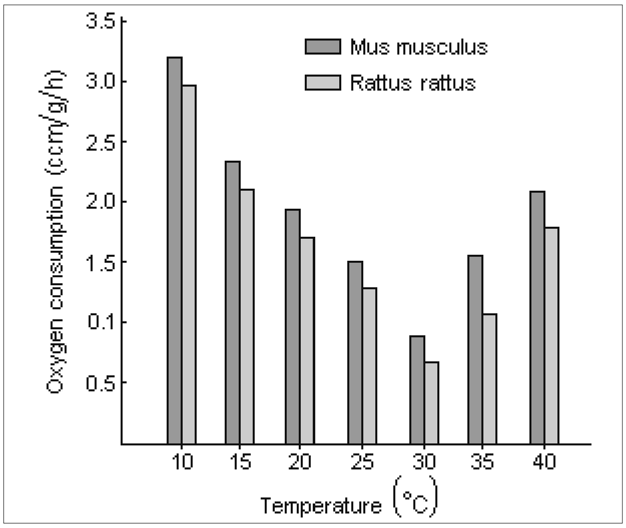

Figure 2: Effect of temperature on resting oxygen consumption rates of the mice Mus musculus and rat Rattus rattus. Each point represents the mean of 8 to 10 measurements for each species.

(experimental value=1.94 ccm O_2/g/h), while it was 1.91 for *Rattus rattus* when the mean body weight was 120.04 g (experimental value=1.70 ccm O_2/g/h). There was a difference between the experimental and estimated values.

The mice *Mus musculus* of small size had a higher heat production (9.31 kcal/g/h) than the large size one *Rattus rattus* (8.16 kcal/g/h).

The statistical analysis show that the data of oxygen consumption was highly significant difference at different temperatures (p<0.05). For each increase in temperature (5°C) there is a general decrease of oxygen consumption up to 30°C, then a gradual increase in oxygen consumption takes place as temperature increases (Figure 2).

DISCUSSION

The relation of oxygen consumption which provide a simple estimation of metabolic rate to size of animals has been considered in the present study at various degrees of temperatures.

The tendency of the variation in the rate of energy metabolism of animals with body weight is direct relationship as it has been discussed by Brody (7) and Zeuthen (30).

Benedict (4) observed that the oxygen consumption of *Iguana tuberculata* is increased with the increase of body weight of animals.

The present results are in disagreement with the above cited studies, as the mice *Mus musculus* of small size (15.47 g) had a higher rate of experimental oxygen consumption (1.94 ccm/g/h) than the large size species

Rattus rattus (120.04 g) which had a lower amount of oxygen consumption (1.70 ccm/g/h).

Moreover, the present data show that the mice *Mus musculus* of small size had a higher heat production than the large size one *Rattus rattus*.

Concerning the influence of temperature, the oxygen consumption per unit weight of the two experimental animals decrease for each increase in temperature (5ºC) up to 30ºC, then a gradual increase in oxygen consumption as temperature (i.e. the zone of thermal neutrality lies around 30ºC.

Comparing these findings with the mean burrow temperature of rodents (6), mean external temperature affected oxygen consumption of some other rodents inhabiting different Egyptian habitats (15) or the mean burrow temperature of Jerboa *Jaculus jaculus* inhabiting desert area of Kuwait (9), it is clear that the zone of thermal neutrality is nearly the same range indicating that the animals select, in their burrows, conditions acting as suitable shelters that enable them to avoid expenditure of more energy during their periods of rest.

Hudson (13) discussed this adaptive character for the desert rodents and reported that the life in desert required an adaptation not only to the elevated and variable temperatures throughout the day but also to the limited amount of food and water.

The lower rates of metabolism in desert mammals were also discussed by several other authors (8,11,17-19, 26, 28).

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