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Heat Production Determined by the Respiration-Calorimetric Method and Body Balance Method

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SUMMARY

Amounts of heat production determined by two indirect calorimetric methods, **i.e.,** respiration—calorimetric method and body balance method were compared. In this report the apparatus, its operation and computation procedures for Haldane respiration-calorimetry modified by Han as well as procedures for body balance method are described.

It was found that the heat production measured by two methods are similar.

INTRODUCTION

Many nutritionists confirmed that the indirect calorimetry is less expensive both in time and apparatus than direct calorimetry. Therefore, the indirect method has been preferable to the direct method for these reasons.

The indirect method of determining the heat production of an experimental animal is essentially a chemical method in contrast to the physical measurements employed in direct calorimetry. Since the two methods have been found to agree with less than 1 percent error in operation of respiration—calorimeters where both indirect and direct measurement have been made, the simpler indirect measurement has been more extensively used.

Commonly used method of indirect calorimetry can be classified as follows:

(1) Respiration-calorimetric method

(2) Body balance method

(3) Nitrogen-carbon balance method.

An attempt has been made to compare the value of heat production determined by two different method of indirect calorimetry, **i.e.,** respiration-calorimetric method and body balance method in the present studies.

EXPERIMENTAL PROCEDURE

Respiration-Calorimetric Method

The respiratory exchange of 7 rats was measured by means of a Haldane apparatus modified by Han (1965). This apparatus (Fig. 1) consisted of a system operated under negative pressure to move atmospheric air through a train of gas traps into the animal chamber at the rate of 2 l per minute and from the chamber through a train of traps, **i.e.,** as in open-circuit calorimetry.

From the incoming air just before its entrance into the chamber, the CO_2 was absorbed by ascarite and the water vapor was absorbed by anhydrous granular magnesium perchlorate. Thus, the animal in the chamber inspired air free from CO_2 and water. From the air leaving the chamber (which includes the gas expired by the animal and the portion of the incoming air not used by animal), the water and CO_2 were absorbed by dehydrite and ascarite, respectively. The respiratory exchange was measured during 24-hour periods. The mechanics of this measurement

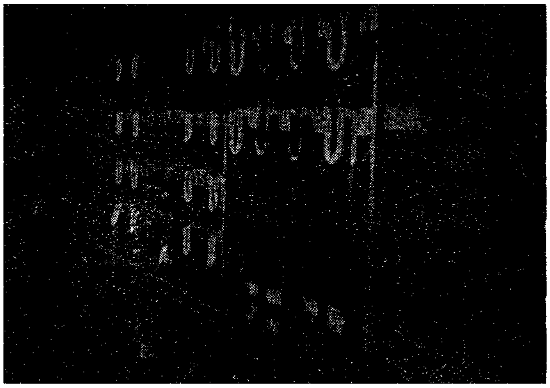

Fig. 1. Respiration-Calorimetric Apparatus

consisted of determining the weights of: (a) the animal and the feed cup separately, (b) the animal chamber, animal, feed cup and water bottle, and (c) the ascarite tubes and the dehydrite tubes separately.

The amounts of CO_2 and water produced by the rats represented the difference between the initial and final weights of the ascarite and dehydrite, respectively. The amount of oxygen (O_2) consumed was computed as follows:

Weight of O_2 consumed=Weight of water+weight of CO_2+(final weight of animal chamber—initial weight of animal chamber.)

Then, the respiratory quotient (R.Q.) was computed as follows, assuming that 1 gm of CO_2 is equal to 0.5094 1 and 1 gm of O_2 is equal to 0.6998 1:

$$\text{R.Q.}=\frac{CO_2 \text{ produced (gm)}\times 0.5094}{O_2 \text{ consumed (gm)}\times 0.6998}$$

Since in the metabolism of protein 4.76 1 of CO_2 is produced, 5.94 1 of O_2 is consumed and 26.51 kcal of heat is produced per gram of urinary nitrogen produced, the use of these factors provides the means for computing the non-protein R.Q. as follows:

$$\text{Non-protein R.Q.}=\frac{CO_2 \text{ produced}-CO_2 \text{ from protein oxidation}}{O_2 \text{ consumed}-O_2 \text{ used for protein oxidation}}$$

The computation method is illustrated with the following data representing the average rat in the 2-meal group.

(1) CO_2 produced/day 10.7761 1

(2) O_2 consumed/day 10.5478 1

(3) R.Q. (1)/(2) 1.03

(4) Urinary nitrogen/day 0.3335 gm

(5) Metabolism of protein

CO_2 from protein oxidation: 0.3335×4.76*1=1.5875 1

O_2 consumed in protein oxidation: 0.3335×5.94*1=1.9810 1

(6) Non-protein CO_2 10.7661−1.5875=9.1786 1

(7) Non-protein O_2 10.5478−1.9810=8.5668 1

(8) Non-protein R.Q. (6)/(7) 1.078

(9) Volume of CO_2 produced from synthesis of fat from carbohydrate (CHO) is: volume of CO_2—volume of O_2=0.6618 1

(10) Heat production

from oxidation of protein: 0.3335×26.51*=8.841 kcal

from oxidation of CHO: 8.5668×5.047*=43.237 kcal

from synthesis of fat: 0.6618×1.09*=0.667 kcal

Total heat production 52.745 kcal

* factors adapted from Swift and French (1954).

Body Balance Method

Heat production can also be obtained by body balance method. The computation rests in the law of conservation of energy and, thus, heat production is equal to the dietary minus the sum of energy of excreta and body gain. This procedure can be used to determine the heat production over a long period of experiment with relatively small animals. It is claimed that this method is more accurate than other methods.

The method may be described as follows:

Experimental rats were fed in individual metabolism cages (Fig. 2) with careful measurement of food intake and collection of excreta. In this experiment 8 rats were sacrificed to establish the initial baseline body composition and energy value of animals exposed to treatment at beginning of experiment. At the termination of the experiment, the rats were fasted for 18 hours to obtain the Shrunk Body Weight (SBW). Then, the rats were killed by putting them in a closed glass jar with ether-moistened cotton for about 2 to 3 minutes.

The rats were dissected to the degree needed to remove the digestive tract. After removal of the digestive tract contents, the rats were weighted to obtain the Empty Body Weight (EBW). The total body was kept at −23°C until freeze dried. After freeze drying, the body was ground with dry ice through a Wiley mill and samples were prepared for chemical analysis.

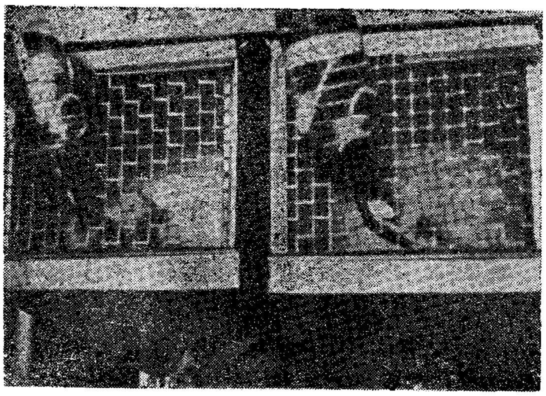

Fig. 2. Metabolism Cage

Heat of combustion values were determined on 1 to 2 gm samples of feed and dried feces, dried urine and body tissues with an adiabatic bomb calorimeter.

The urine was prepared for the determination of heat combustion values as follows: (a) 100-ml samples were pipetted into plastic containers of known weight, (b) the urine was frozen and then freeze-dried for 3 days, (c) gross energy values were determined on the mixed, dried solids, and (d) since sulfuric acid had been added to the urine as a preservative, a mean acid correction value was determined for urine not treated with acid.

RESULTS AND DISCUSSIONS

The amounts of heat production determined by the two indirect calorimetric methods for two different feeding system are compared in Table 1 and 2.

Table 1 : Heat production measured by respiration-calorimetric method and body balance method when diets were fed ad-libitum

Methods	Total heat Production	Heat production Per MBS	Proportion of GE
	k cal/day	k cal $/W_{kg}^{0.734}/$ day	%
Reapiration-calorimetric Method	60.81	140.12	80.04
Body Balance Method	57.08	138.73	82.08

It was found that heat production per unit of metabolic body size determined by two methods are very similar.

Table 2 : Heat production measured by respiration-calorimetric method and body balance method when diets were fed 2-meal per day.

Methods	Total heat Production	Heat Production Per MBS	proportion of GE
	kcal/day	kcal / $W_{kg}^{0.734}$ / day	%
Reapiration-calorimetric Method	52.58	118.01	69.05
Body Balance Method	52.75	121.81	69.12

Amounts of heat production determined by respiration-calorimetric method for rats fed two-meal per day are similar to the values obtained by the method of body balance as is indicated in Table 2.

It is interesting to note the fact that total heat production per unit of metabolic size per day and as a percentage of dietary gross energy (GE) ingested were considerably ($P<0.005$) lower for the rats fed 2 meals per day than for the rats fed ad libitum.

It may be concluded that the body balance method can be used to determine the heat production of small size of experimental subjects.

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