ANALYSIS OF THE ENERGY METABOLISM IN DIFFERENT SPECIES OF LUMBRICIDAE

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Abstract
The lumbricidae have no respiratory system, their breathing is done through the skin which is highly vascularized witch is kept moist by its very existence, by skin glands and then if necessary by removing the coelomic fluid through the dorsal pores. This process of breathing is specific to earthworms which are said to have a high degree of adaptation to specific conditions. The present study aims to determine the breathing intensity in different species of lumbricidae in various stages of development. The species analyzed were: Allolobophora chlorotica (adult), Aporrectodea rosea rosea (adult), a Dendrobaena alpina (adult), Dendrobaena alpina (juvenile), Aporrectodea rosea rosea (juvenile), Octolasion lacteum (adult), Octolasion lacteum (juvenile). It was observed that the breathing rhythm of the animals ranged from 0.0029 to 0.0968 µm CO_2/g/s both interspecifically and intraspecifically. Comparing the individual biomass with the CO_2 quantity recorded by each of the species, we found no relationship between biomass and breathing. There was some indication that discontinuous patterns, irrespective of whether the animal is active or at rest, contributed to the variability of respiration rates. To reduce such sources of variability it is recommended to standardize the environmental conditions during the measurements as far as possible and to choose measurement periods long enough to detect differences in the respiration pattern.

Keywords: breathing, lumbricidae, stages

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1. INTRODUCTION

The lumbricidae have no respiratory system. Their breathing is done through the skin which is highly vascularized. It is kept moist by its very existence, by skin glands and then if necessary by removing the coelomic fluid through the dorsal pores.
As a result of the metabolic, muscle and digestive activity, O_2 is consumed CO_2 removed. The latter is heavier than air and accumulates in the lower part of the gallery and can reach quite high concentrations. If they exceed 25%, they threaten the animal life.
They have a calcium producing gland in the front part of the body, which stores calcium carbonate in crystalline form. Oxygen enters the blood through the wet skin and tissual CO2 also enters the blood in the form of soluble calcium bicarbonate, which leads to the calcium producing gland, where it turns into insoluble calcium carbonate. It is then disposed as crystalline grains in the intestine and taken out with feces. These crystalline grains are closely linked to a number of mucous substances, water, and they maintain a microgranular structure of the soil allowing air and water infiltration.
The calcium producing gland is therefore an additional organ of the respiratory system in an environment heavily polluted with CO_2. Fixing this gas, it allows the air absorption from the outside, by the fact that oxygen is consumed creating a low pressure. The skin surface should be always wet, so that oxygen can be absorbed and carbon dioxide eliminated. If the lumbricidae skin is dry because of the sun or other adverse conditions, they will not survive because the gas exchange no longer occurs. Earthworms are able to tolerate dehydration to a certain extent, to induce a temporary latent state (diapause) and produce cocoons resistant to unfavorable periods (Edwards *et al.*, 1996).
This process of breathing is specific to earthworms which are said to have a high degree of adaptation to specific conditions. No other organism has ever achieved such physiological and biochemical performance.

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2. MATERIALS AND METHODS

Determination of breathing intensity was done using the carbon dioxide analyzer S151. It measures the concentration of CO_2 in the air passed through the breathing room, in comparison with CO_2 in the air before passing through the breathing room. The device is equipped with a storage bag, hence the air that will be used for determinations (to avoid influences caused by people around). The air is pumped into the device using an electric pump, which can adjust the air flow (in our case 400 ml/min). The device is connected to the computer via an interface. The results are expressed in ppm, and the following formula is applied for conversion in μmol CO_2/l.

$$\frac{\Delta CO2}{22.415} \times \frac{T+C}{T} \qquad (1)$$

The results were then reported, multiplying by 0.0066l/s, the corresponding air flow of 400 ml/min. The final results were reported to g and expressed in μmol CO_2/g/s.
The tests were conducted on several species of lumbricidae in various stages of development, collected by hand sorting and taken to the laboratory in containers with moist soil.
Before starting the experiment, each individual of the lumbricidae species was weighed using the analytical balance while the temperature (T in ºC) was measured in the laboratory. The laboratory temperature was 26.7ºC. After establishing the breathing rate determinations were made on the species. There were nine different experimental variants on various lumbricidae species. The species determination was performed in the laboratory [6, 10].

3. RESULTS AND DISCUSSION

It was observed that the breathing rhythm of the animals ranged between 0.0029-0.0968 μm CO_2/g/s. These variations were found among species, within species and from individual to individual (Table 1).

Table 1. Breathing rate, individual biomass (g), development stage of lumbricidae species

V	SPECIES	STAGE	BIOMASS (g)	CO_2 μm/g/s
V1	*Allolobophora chlorotica*	A	659.5	0.0113
V2	*Aporrectodea rosea rosea*	A	661.1	0.0302
V3	*Dendrobaena alpina*	A	663.4	0.0095
V4	*Dendrobaena alpina*	J	657.9	0.0312
V5	*Aporrectodea rosea rosea*	J	672.9	0.0337
V6	*Aporrectodea rosea rosea*	J	682.9	0.0728
V7	*Octolasion lacteum*	A	674.8	0.0035 6
V8	*Aporrectodea rosea rosea*	J	733.1	0.0968
V9	*Octolasion lacteum*	J	710.6	0.0029

V-variant; A-adult; J-juvenile

Figures 1-9 show the breathing rates of lumbricidae species, using CO_2 - S151 analyzer. *Octolasion lacteum* (juvenile) (0, 0029 μm CO_2/g/s) recorded the lowest quantity of CO_2, while the highest value of CO_2 was observed in a juvenile *Aporrectodea rosea rosea* species (0, 0968 μm CO_2/g/s). The analysis of the nine species of lumbricidae shows that the species with a lower individual biomass which are usually smaller species recorded higher CO_2 quantities. Also, the CO_2 quantity was higher in juveniles than in adults.

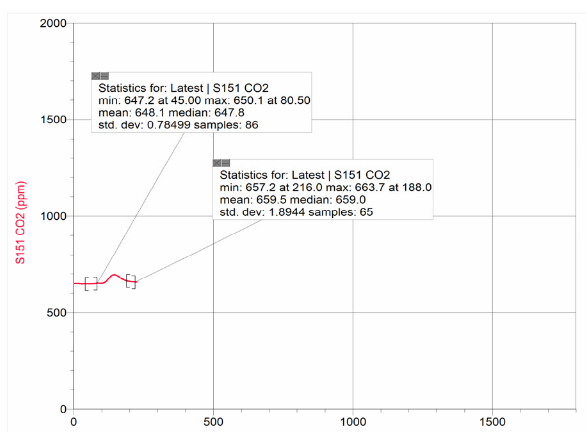

Fig.1. Quantity of CO_2 in *Allolobophora chlorotica* (adult) species using S151(V1) analyzer

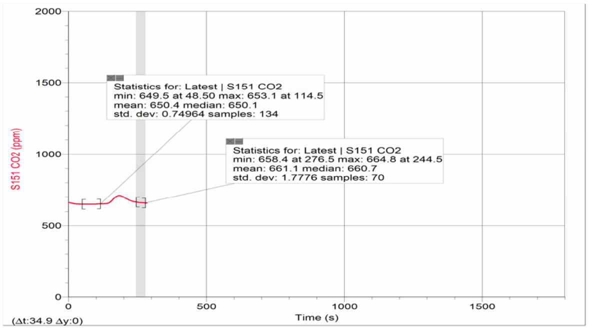

Fig. 2. Quantity of CO_2 in *Aporrectodea rosea rosea* (adult) species using S151(V2) analyzer

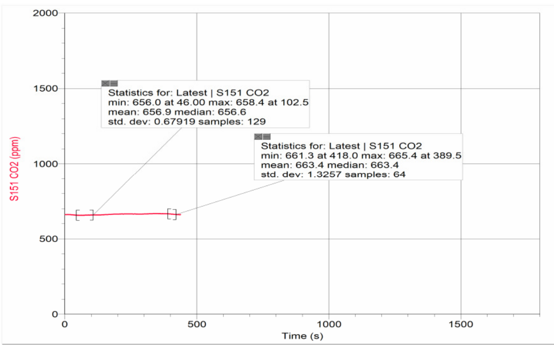

Fig. 3. Quantity of CO_2 in *Dendrobaena alpina* (adult) species using S151(V3) analyzer

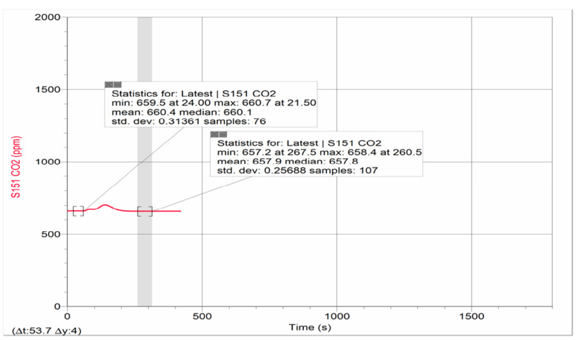

Fig. 4. Quantity of CO_2 in *Dendrobaena alpina* (juvenile) species using S151(V4) analyzer

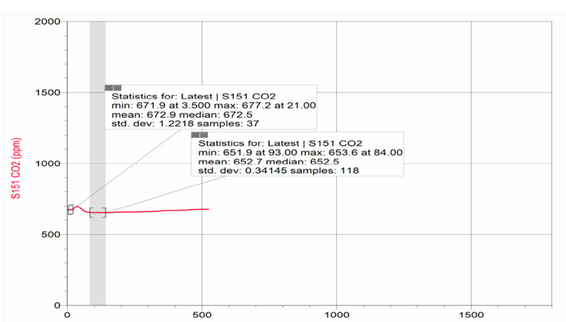

Fig. 5. Quantity of CO_2 in *Aporrectodea rosea rosea* (adult) species using S151(V5) analyzer

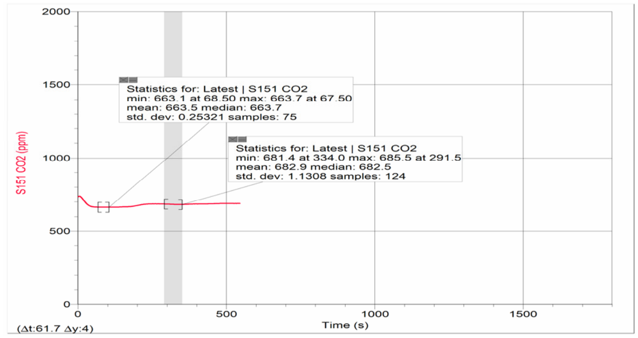

Fig. 6. Quantity of CO_2 in *Aporrectodea rosea rosea* (juvenile) species using S151(V6) analyzer

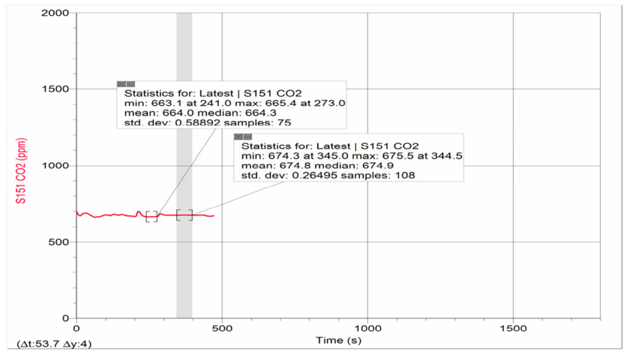

Fig. 7. Quantity of CO_2 in *Octolasion lacteum* (adult) species using S151(V7) analyzer

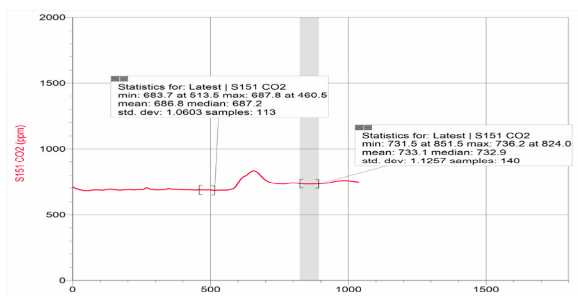

Fig. 8. Quantity of CO_2 in *Aporrectodea rosea rosea* (juvenile) species using S151(V8) analyzer

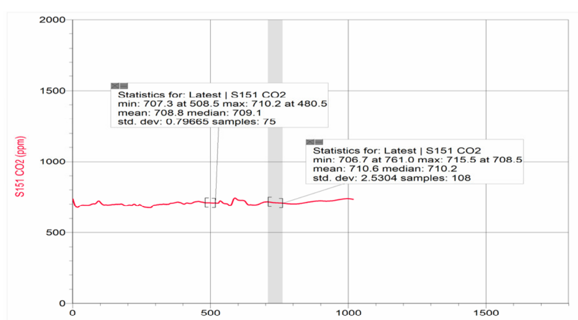

Fig. 9. Quantity of CO_2 in *Octolasion lacteum* (juvenile) species using S151(V9) analyzer

In *Aporrectodea rosea rosea* for example, which is a smaller species, the breathing rate was higher than in *Octolasion lacteum* which is a larger species, or *Aporrectodea rosea rosea* in comparison with *Allolobophora chlorotica* which is also larger than *Aporrectodea rosea rosea* and *Dendrobaena alpina*. The breathing rate of earthworms seemed to decrease with increasing biomass (ie, with the decreasing ratio between body surface area and biomass).
This trend was observed by Mendes and Valente (Mendes and Valente, 1953), who studied the breathing rate of three different-sized species of earthworms. Bolton (Bolton, 1970) also measured the breathing rate of *Lumbricus castaneus* and *Dendrobaena rubida* earthworm species at 10ºC and reported values between 75–100 $\mu lCO_2h^{-1}g^{-1}$.
Larger species of lumbricidae such as *Lumbricus terrestris* had values between 70–90$\mu lCO_2h^{-1}g^{-1}$; due to a diurnal rhythm, breathing may be higher during certain times of the day (Edwards and Bohlen, 1996) quoted by Bernhard Forster et al., (Bernhard *et.al.*, 2006).
Earthworm breathing is affected by temperature, body size, diurnal rhythms, activity and the soil characteristics. Smaller species with a greater surface area for gaseous diffusion breathe more in terms of oxygen uptake per g body tissue. Earthworms in tropical areas breathe faster than those in temperate regions because of high temperature.
Uvarov (Uvarov, 1998), quoted by Bernhard Forster et al., (Bernhard *et.al.*, 2006) demonstrated the temperature dependence of breathing in *Dendrobaena octaedra* species, with breathing rates of 32.3 $\mu lCO_2h^{-1}g^{-1}$ at 5°C and 148.5 $\mu lCO_2h^{-1}g^{-1}$ at 25°C.
Studies on the direct contribution of lumbricidae to the release of CO_2 in the breathing process were carried out by Mishra and Dash,1980, Heneghan et al. 1999, Hofer et al., 2001.

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