Metabolic Rate of *Gromphadorhina portentosa* (Madagascar Hissing Cockroach) in Controlled Environments

Abstract

This experiment was conducted in order to test the gas exchange or metabolism of the ectotherm; *Gromphadorhina portentosa,* commonly known as the Madagascar hissing cockroach. One (1)

G.portentosa was set in a clear experimental container and observed for approximately ten (10) minutes at a room temperature of 24ºC. Following this observation the apparatus containing *G.portentosa* was submerged in cold water to provide a cold environment for the first run. Then it was submerged in warm water to imitate a hot environment. The carbon dioxide level and the temperature of the apparatus were observed for approximately ten (10) minutes in five (5) minute increments for both runs. Under normal conditions such as the natural environment of *G.portestosa* carbon dioxide (CO_2) and oxygen (O_2) exchange increases as temperature increases allowing for more free movement. The metabolism experiment proposed that in hotter temperatures the cockroach showed more gas exchange of CO_2 and also displayed more movement.

Introduction

Metabolism is the totality of an organism's chemical reactions to maintain life. A metabolic pathway usually comprises several steps such as a series of chemical reactions catalyzed by enzymes. Thus the reactants of one reaction are the products of the previous one. This cycle occurs repeatedly yielding processes for cell growth, reproduction, response to environment, survival mechanisms, sustenance, and maintenance of cell structure and integrity. It is made up of two categories: catabolism and anabolism. Catabolism is the degradative pathway that breaks down complex organic molecules such as fats, carbohydrates, and proteins into simpler molecules such as pyruvate, Co_2, and H_2O causing an oxidation reaction that releases free energy. Anabolism is the constructive pathway that consumes energy to build complex molecules from simpler ones, such as the formation of glucose from two pyruvate molecules, which are sometimes called biosynthetic pathways. The Madagascar hissing cockroach is an ectothermic insect, which means it regulates its body temperature by exchanging heat with its surroundings unlike endothermic insects that generate heat by internal metabolic pathways to maintain body temperature. (Campbell and Reece 2008) *G.portestosa*'s natural environment is the tropical dry forest and tropical rainforest. Their lifestyle includes the breaking down of decaying plant and animal matter and their usual diet includes rotting fruits and fungi. They are categorized as herbivores. They live in large colonies containing subsets of smaller colonies within the large colony. One male will dominate and hold a territory with several females. If another male enters, it is pushed out of the territory by the dominate male. Females may come and go within these male dominated territories. (Full and Herreid 1984) In the experimental examination of *G.portestosa*, levels of CO_2 were tested at different temperatures of hot or cold environments. It was predicted that, with increased temperature metabolic exchange of CO_2 and O_2 would also increase thus allowing free movement of *G.portentosa* closely mimicking its natural environment. This prediction was predicated by knowing a brief history and knowledge of the natural habitat of *G.portestosa*

Methods

Preparation

G.portestosa used in the experiment was taken from a container where all the roaches were held and placed into a two liter clear container allowing for behavioral observations during incremental increasing and decreasing temperature changes. A Vernier Labquest instrument was used to analyze the O_2 and CO_2 levels inside the apparatus by inserting probes through two holes on top of the apparatus yielding digital readings of O_2 and CO_2 levels at specified time intervals. In this experiment the levels of CO_2 were of greater importance than the O_2 levels. To evaluate a correlation between temperature and rate exchange a thermometer was placed inside the container to get the temperature readings at each time interval.

CO_2 Levels with Respect to Temperature in a Cold Environment

The apparatus containing the O_2 and CO_2 probes and thermometer was placed on the table for a few minutes to get initial readings of CO_2 levels and temperature. The initial temperature inside the container was 24ºC and the initial level of CO_2 was 0.2260%. Next, we placed the apparatus into a tub of ice, inducing a cold environment for *G.portestosa*. This was our first run of the experiment. The emission of gases were read as percentiles and recorded for ten (10) minutes with five (5) minute intervals. The temperature was recorded at each time interval as well. All data was recorded in lab notebooks for later usage. From this data an average of O_2 and CO_2 levels was calculated.

CO_2 Levels with Respect to Temperature in a Hot Environment

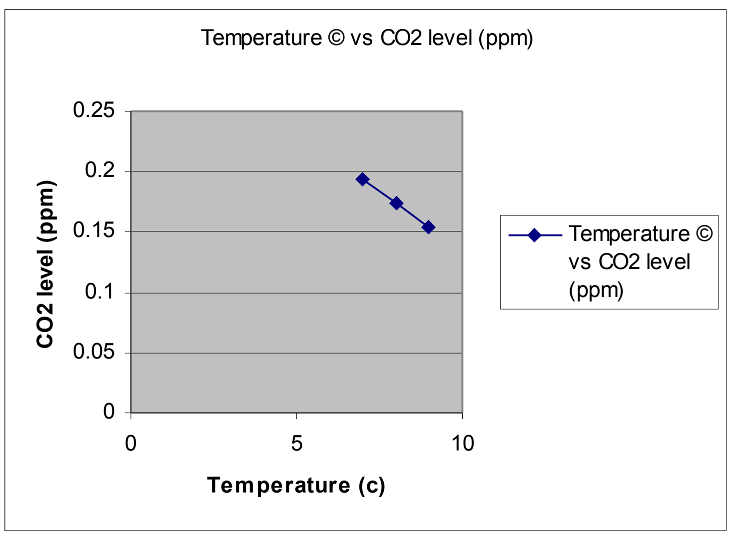
To prepare for run two (2), the ice was dumped out into a sink and moderately hot water was filled into the tub. The apparatus was then placed on the table for a few minutes to obtain initial readings as done for run one (1). After obtaining initial readings, the apparatus was placed into the tub of hot water and was observed for the next ten minutes as well. To prevent possible damage to the probes a book was used to keep the apparatus in place and prevent it from floating and tipping over. As in run one (1) the percentage of CO_2 level was recorded every five minutes along with the temperature. Movement of the roach was also observed and noted. All data was recorded in lab notebooks for later usage. From this data the average CO_2 and O_2 levels were calculated. Data from both runs were transferred from lab notebooks and prepared in Microsoft Excel.

Results

CO2Levels with Respect to Temperature in a Cold Environment

The initial temperature of the container was 24ºC and the initial CO_2 level 0.2260%. Every five minutes the analyzed data showed that as temperature decreased, levels of CO_2 increased. Movement of *G.portentosa* was minimal during the initial readings and to about ten (10) minutes into the experiment. Movement was observed approximately ten (10) minutes into the experiment after the container was slanted slightly. When the apparatus was slanted an increase in CO_2 levels was observed. Movement stopped around twelve (12) minutes. Movement of *G.portentosa was* pertinent in this experiment but was observed and recorded in this report.

In Graph 1, the relationship between temperature and CO_2 level is depicted to show the increase in CO_2 level as temperatures decreased.



Graph 1. Relationship between temperature I degree Celsius and CO_2 (%) level in a cold environment.

In Table 1, the emission of CO_2 along with the temperature at each time interval is shown.

Table 1. CO_2 levels at various temperatures in a cold environment.

Time Elapsed (mins)	Temperature (ºC)	CO_2 Level (%)
0	9	.1542
5	8	.1739
10	7	.1937

The calculated average change in CO_2 (%) level per degree Celsius of change in temperature was 0.01975%. These calculations were derived by taking the total change in the CO_2 percentage and dividing it by the total change in temperature.

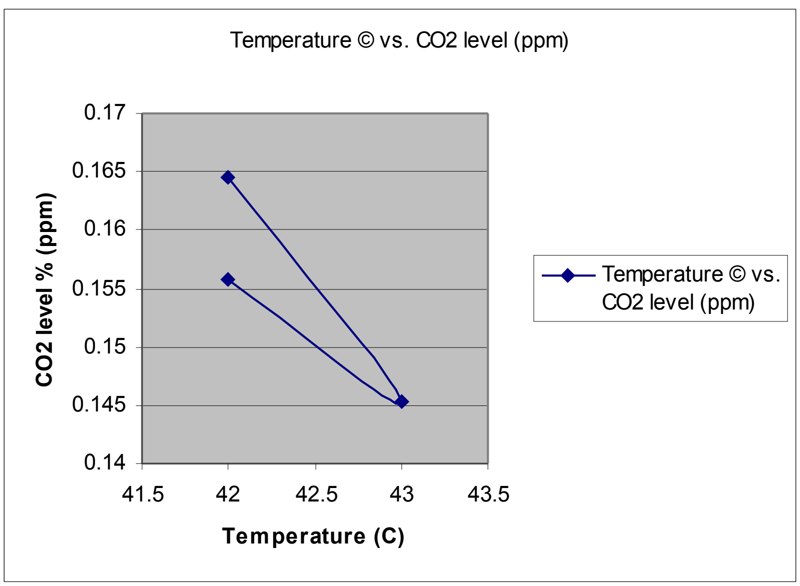
CO_2 Levels with Respect to Temperature in a Hot Environment

Initial temperature for this run was 42ºC with initial readings of CO_2 level at 0.1645%. Every five minutes the observed data showed that an increase in temperature was directly proportional to an increase in CO_2 levels. Movement observed was very minimal during the time period between zero (0) and seven (7) minutes of the experiment however towards the end of the ten (10) minute period the cockroach was moving fast and freely about the apparatus. Below in Table 2, the emission of CO_2 gases are shown as well as the temperature for each five (5) minute interval.

Table 2. O_2 and CO_2 levels at various temperatures in moderately hot temperatures.

Time Elapsed (mins)	Temperature (ºC)	CO_2 Level (%)
0	42	.1645
5	43	.1453
10	42	.1557

In Graph 2, the relationship between temperature and CO_2 (%) level is graphed to easily view the rise in CO_2 level as temperature in degree Celsius increased.



Graph 3. Relationship between temperature in degree Celsius and CO_2 (%) level in a hot environment.

The calculated average change in CO_2 (%) level per degree Celsius of change in temperature was 0.0148%. These calculations were derived by taking the total change in O_2 or the CO_2 percentage and dividing it by the total change in temperature.

Discussion

The stated hypothesis said, the higher the temperature the more CO_2 is going to be exchanged and the roach will be freely moving because this closely mimics its natural environment. As a result, the prediction was proven correct, through observation and from the data collected. In the hot environment, O_2 and CO_2 levels increased as the temperature inside the apparatus increased. In the cold environment, O_2 and CO_2 levels decreased as temperature decreased. All data collected from this experiment and presented in this report fail to reject the null hypothesis stating that that as temperature increases CO_2 levels increase allowing free movement of *G.portentosa*. During observation of *G.portentosa* when placed in a cold environment it was apparent that the insect did not acclimate well to the cold environment evidenced by minimal movement and gas exchange and a hissing noise heard while in the colder environment. In the warmer environment *G.portentosa* acclimated very well as evidenced by observed increase in O_2 and CO_2 exchange, increased movement and a lack of hissing. Although the movement of the cockroach was not relevant to the metabolic rate or gas exchange, *G.portentosa* showed more movement in the warmer environment. All graphs and tables in this report give a visual relationship between levels of CO_2 at varying temperatures. Experimental data and observation was compared to others in the laboratory, and seemed to yield the same results; hotter temperatures corresponded to more O_2 and CO_2 gas exchange. This correlation between gas exchange and temperature includes but is not limited to serving as an indicator of *G.portentosa*'s ability to acclimate to certain environments. For example O_2 enters the cockroach through tiny breathing tubes called tracheae to all of the body parts CO_2 is then released. (Bradley and Contreras 2009). The cockroach has the ability to press air through its spiracles to make a hissing noise as a sign of aggression, hence the name of the cockroach. Gas exchange increases when the cockroach is comfortable with the environmental conditions regardless if the conditions are in a laboratory setting or its natural environment (Blackburn and Chown 2008). During this experiment there were no major complications. However for future experiments results may be improved if the sample size were increased. In addition to sample size the subject should not only be observed at room temperature but should also be observed for a period of time after being aggravated, inducing hissing. At this time gas exchange should be measured before the manipulating the temperature. By doing this it would be possible to show whether or not aggravation and temperature are dependant or independent of each other in relationship to gas exchange.

Literature Cited

Articles:

Blackburn Tim M, Chown Steven L, Marais Elrike, Terblanche John S, White Craig R. 2008. Scaling of gas exchange cycle frequency in insects. Biol Lett. 4(1): 127-129

Bradley TJ, Contreras HJ. 2009. Transitions in insect respiratory patterns are controlled by changes in metabolic rate. Journal of Insect Physiology.

Campbell, Reece. 2008. Biology. 8th ed. San Francisco (CA). 863-63 p.

Full Robert J, Herreid II Clyde F. 1984. Cockroaches on a treadmill: Aerobic running. Journal of Insect Physiology. 30(5):395-405.

The Big Zoo [Internet]. C2010. Magnolia (TX); [cited 2010 March 2010]. Available from: http://www.thebigzoo.com/Animals/Madagascar_Hissing_Cockroach.asp