

Effect of temperature on metabolic rate of larvae



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ABSTRACT

This experiment was designated to investigate the effect of temperature on metabolic rate of *Lucilia sericata* larvae. Water bath has been used to set up the different temperatures of water at 30°C, 35°C, 40°C, 45°C, 50°C and 55°C. *Lucilia sericata* larvae were chosen to show the effect of different temperature on biological reaction of organism. The active *Lucilia sericata* larvae of the same size were soaked in different temperature of water for about 30 seconds and the number of wriggles was counted in one minute period. From the data, Q_{10} was calculated and it represented the metabolic rate of an organism. Results showed that the metabolic rate increases as the temperature of water increases. An analysis using Pearson product-moment correlation coefficient showed a statistically significant positive strong linear relationship between temperature and metabolic rate of organism since calculated r value was greater than critical value at 5% significant level.

RESEARCH AND RATIONALE

The purpose of this experiment is to investigate and verify the relationship between different temperatures on metabolic rate of maggots of *Lucilia sericata*. All of the chemical activities that occur in living organisms are metabolism. 7

Metabolism is all chemical and physical reactions in living organism to allow growth, maintain life and body functions. These activities allow organisms to grow, form energy, maintain structure, convert and store energy from nutrients. Metabolism can be divided into two which are catabolism and anabolism. Catabolism include oxidative break down of organic molecules

while anabolism uses energy to construct molecules such as nucleic acid and proteins. 2, 7

The rate of metabolism of organism are affected by many different factors such as size and mass of organism, temperature, diet, age, hereditary and hormones. The size of an organism and temperature affects metabolic rate of an organism in different mechanism. 11

Bigger body size causes the heat to accumulate more efficiently as large body size has low surface area to volume ratio. Large animals usually has low metabolic rate because they will having overheating problem if they had high metabolic rate. 9, 11

Temperature can give major effect to organisms as it can influence the rate of all biochemical reactions. Higher temperature can increase the activity of enzymes, oxygen consumption and energy thus metabolic rate of organism is higher. 1

A study by D. Berridgan and L. Patridge shows the evidence that metabolic rate and temperature are strongly dependent and they investigated on adult *Drosophila melanogasteras*. Their report shows that metabolic rate increases with temperature as they measure the speed walking of *Drosophila melanogasteras* at two different temperatures, 180C and 250C. They did research about different temperatures and altitude on metabolic rate. Their results show that metabolic rate at different altitude did not differ much compared to temperatures at different altitudes. 4

Temperature is one of important factor in enzyme reactivity. Enzymes are biological catalysts that speed up chemical reactions¹². Enzymes are very specific as it only catalyzes a few reactions and determines metabolic pathways of a cell. Metabolic rate increases as temperature increases, up to the point where the enzyme is denatured⁵. Temperature coefficient, Q₁₀ can express the relationship between metabolic rate and temperatures as it represent the increase in reaction for every 10 degree rise in temperature⁴.

The graph shows that metabolic rate increases with temperature. At 40°C, the rate decreases back because the enzymes are denatured. Metabolic rate changes with temperature shows the effect of higher thermal energy of reactants and effectiveness of cellular enzymes increases. At higher temperature, the weak bonds that hold enzymes at their specific site starts to break and metabolic activity are disrupted¹¹.

The way organisms respond to the environment is behavior. One of the environmental conditions which may affect the maggots is temperature. Maggots are an example of ectotherms, rely on temperature of surrounding to determine their internal temperature and thus their metabolism. They respond and move at a rate which is accordance to ambient temperature¹⁰. Hence, this experiment is an attempt to determine the correlation between different temperature and metabolism.

The outcomes of this experiment can be applied to all ectotherms as their body temperatures fluctuate with changes in the ambient temperature. Their behavioural and physical adaptations help them to survive in extremes

climate10. This study is also important to prove that metabolic rate of organisms change with temperature to ensure their survival.

EXPERIMENTAL HYPOTHESIS

The higher the temperature, the higher the metabolic rate of *Lucilia sericata* larvae

NULL HYPOTHESIS

There is no correlation between temperature and metabolic rate of *Lucilia sericata* larvae

PLANNING

A trial experiment had been conducted to determine the most suitable methods and procedures to be used. Besides that, the most suitable range of temperature is determined.

Trial 1: paper versus water bath

This trial is designated to choose which method is the best for this experiment in which paper or water bath to act as subjects at different temperatures.

For paper, I took a piece of paper and draw a circle with radius 5cm. the paper was put above a beaker of ice for about a minute and then a maggot of *Lucilia sericata* was put in the middle of the circle. At the same time, stopwatch is started and the time taken for it to cross the line is recorded.

For the method by using water bath, I took a maggot of *Lucilia sericata* and put it at the bottom of a test tube and soaked it in water bath for a while. Then, I counted number of wriggles take place in one minute period.

From this trial, I learned it was hard to keep the temperature of paper constant and the temperature can change rapidly and gradually throughout the experiment. Besides that, *Lucilia sericata* larvae sometimes did not always move forward to cross the line yet move to side of circle.

So, water bath is the most suitable to be used instead of paper to represent temperature of surrounding. However I had to use wire gauze in the real experiment so that the organism would not move out of the test tube when the test tube is soaked.

Trial 2: The most suitable method

This trial was done to choose the most suitable procedure for this experiment and decide whether number of wriggles or time taken should be kept constant. Firstly, an active *Lucilia sericata* larva is put at the bottom part of a test tube soaked in a water bath of temperature 30°C and 40°C for 30 seconds. After that the number of wriggles in one minute was counted.

The trial was repeated by using different *Lucilia sericata* larva but the number of wriggles is kept constant. Time taken for *Lucilia sericata* larva to complete 70 wriggles after being soaked in water bath is measured.

Based on the trial results, there was more significant difference when number of wriggles is calculated in one minute period instead of measuring the time taken for 70 wriggles complete. The experiment gives more reliable

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result when the time act as fixed variable rather than number of wriggles because maggots is an organism and the rate of their movement is not constant. Therefore, time acts as constant variables and number of wriggles is counted in a fixed period of time.

Trial 3: The range of temperature

This trial was conducted to determine the best range of temperature of water bath for this experiment. At first, a test tube with *Lucilia sericata* larva is soaked in a beaker at 20C for about 30 seconds and number of wriggles in one minute is calculated. The trial is repeated for other temperatures.

At very low and high temperature, the number of wriggles in one minute is very low and no wriggles at all. This shows that the enzymes were not active at these temperatures and metabolic rate of organism is very low.

Temperatures ranges from 300c to 550c were thus chosen for the experiment.

MAIN EXPERIMENT

VARIABLES

Manipulated: Temperature of water bath (0c)

Different temperature of water bath is used to represent the temperature of 300C, 350C, 400C, 450C, 500C and 550C. This temperature need to be kept constant throughout the experiment to make sure that the enzyme in the organism reacts correctly to the temperature.

Responding: Rate of movement of lucilia sericata larvae (metabolic rate)

Rate of movement of lucilia sericata larvae represent metabolic rate of organism and can be calculated by number of wriggles in one minute after being soaked in different temperature of water bath.

Control: Sizes and ages of lucilia sericata larvae, amount of time use for soaking, environmental factors (light intensity, humidity)

Characteristic of lucilia sericata larvae need to be the same including the sizes, ages, and source. The experiment need to be conducted in laboratory to maintain the light source and time taken for soaking were kept constant at 30 seconds.

APPARATUS:

Test tube, wire gauze, Petri dishes, and stopwatch

MATERIALS:

Maggots of lucilia sericata, water bath at required temperatures

1620 words

METHODS

- An active and healthy maggot of lucilia sericata was put in the bottom of a test test tube together with wire gauze
- Water in the water bath is heated up to required temperature, 300c
- The test tube is soaked in the water bath for about 30 seconds.
- In one minute period of time, number of wriggles of maggot of lucilia sericata is counted and recorded.

- The experiment is repeated for temperature 350c, 400c, 450c, 500c and 550c.
- The whole experiment is repeated 5 times to get more reliable results.
- All observations and data were recorded and tabulated in a table.

RISK ASSESSMENT

- Gloves were worn when dealing with *Lucilia sericata* to prevent any infections because it usually carries a lot of bacteria.
- Washed all equipments, hands and surfaces with antibacterial soap to destroy any bacteria,
- All the glass wares such as beakers and test tubes must be handled with care since the apparatus can break easily and can cause injury.
- Be careful when handling the water bath as the water is hot and can hurt your skin.
- Handled the maggots by using forceps gently to prevent it from hurt.

1822 words

RESULTS

STATISTICAL ANALYSIS

For this experiment, Pearson product-moment correlation coefficient (PMCC) is chosen to measure the strength of linear dependence between two variables in this experiment which were temperature and metabolic rate. This statistical test was chosen because there is 'cause-and-effect' association between two variables and the independent variable is under control. 3

Parametric correlation coefficient, r ranges from -1 to 1 only. A value of 0 implies that there is no correlation between the variables. Meanwhile, value of 1 indicates correlation in which y increases as x increases and the value of -1 implies that a linear equation describes the relationship between variables x and y perfectly for which y decreases when x increases. Graph can be used to show relationship and correlation between two factors.

Product moment correlation coefficient, r is calculated by using formula:-

0. 9765 (Positive sign indicates positive correlation between variables)

Value 0. 9765 is almost 1 show that there is strong positive correlation between variables x (temperatures) and y (metabolic rate). According to PMCC table, the value of critical value is 0. 811 at 5% level of significance as the numbers of XY pairs are 6 and degrees of freedom are 4. Value of r is 0. 9765 which is smaller than the critical value (0. 811) at two tail test. 3

An analysis by using product moment correlation coefficient, PMCC showed a statistically positive linear relationship between temperature and metabolic rate of *Lucilia sericata* larvae since calculated r value was greater than critical value at 5% confidence level³. The null hypothesis, H_0 is rejected and it is concluded that there is sufficient evidence to show that there is significant relationship between temperature and metabolic rate.

DATA ANALYSIS

Table 2 shows the number of wriggles of *Lucilia sericata* larvae in one minute period after being soaked in different temperature of water bath for about 30 seconds. There are 6 different temperatures range from 30°C to 55°C had

been investigated. The experiment is repeated 5 times to reduce random and systematic errors that occur during the experiments by calculating the mean value.

From the bar chart, it is clearly illustrated that the rate of movement increases with temperature. The statistical analysis using PMCC, product moment correlation coefficient verified the correlation between different temperatures and metabolic rate of organism.

In this experiment, Q10 is calculated by measuring the rate of movement of *Lucilia sericata* larvae at different temperatures. Q10 is calculated by using the formula in which the rate of reaction of higher temperature relative to the lower temperature. The data and calculation of Q10 are tabulated in table 3. Q10 can represent the metabolic rate of organism. 11

Graph 1 depicts that the increase in Q10 is small for the first three temperatures, 30°C, 35°C, and 40°C but bigger for the higher temperatures. Higher temperature will produce more ATP for contraction of muscles and the organisms move faster. At higher temperature, particles are moving faster due to increased in kinetic energy of particles⁷. Thus, more collisions occur and causing a reaction. Since the higher rate of metabolism supplied them with energy, maggots will move more quickly and thus rate of reaction and Q10 increases¹¹.

Maggots are one of simple organism and rely on temperature of environment to determine their internal temperature and metabolism rate. Maggots are excellent organisms to use in this experiment because there are sensitive

and inexpensive. They respond quickly in environment and change in temperature because they are such a small organisms.

EVALUATION

The results show an increasing in metabolic rate with temperature. However, the increase in Q10 is not consistent and this trend is not a straight line. The maggots could have achieved their fastest rate at room temperature, and therefore a slight increase in temperature does not increase their rate substantially. Besides that, higher temperature shows a dramatic increase in their rate because the warmer temperature was past the optimum temperature and the substrates collide with enzymes more frequently, thus more reaction occur⁵.

Furthermore, the optimum temperature in this experiment is 55°C as the reactivity of the maggots is the highest and they moves very fast at this point. This temperature can be considered high because usually the optimum temperature for enzyme activity is 40°C and over this temperature, the enzymes start to denature¹¹. This phenomenon can explain that the maggots does not fully adapt with the new environment or maybe because the time of soaking is too short for them to climatize.

There are some inconsistent results as there are certain larval that moves faster or slower than others at the same temperature. This problem might be because of their fitness and endurances. Weak maggots might have reduced effectiveness and move slowly than others, thus giving an unreliable result.

Kleiber's Law shows that metabolic rate, R follows exactly $\frac{3}{4}$ power-law of body mass, M with formula $R \propto M^{3/4}$.

There are large samples of maggots was taken for each temperature, giving representative data which reduced the likelihood of inconsistent and anomalous results. For example, the maggot that move slowly and do not respond to change in temperature as the maggots in test tube is soaked in water bath for only 30 seconds to climatize. Besides that, the experiment is replicated five times for each temperature to find the mean and help to improve reliability. 6

Some limitations in this experiment has been identified include the way of counting the number of wriggles of wriggles to calculate the rate of movement and thus determine the metabolism rate. The maggots might not move at a constant rate and sometimes it stops for a while. This might affect the results and this probably happen because the maggots does not climatize well with the temperature. Besides that, the activeness of maggots is different from one to another.

Temperature of water bath must be kept constant throughout the experiment. The compromise temperature was chosen in this experiment as the enzyme does not active at lower temperature and at higher temperature, the proteins in the enzyme begin to change shape and denature⁵. Reaction cannot be completed because the substrate no longer fit into active site thus no energy supply and eventually the wriggles less and finally stops. 5

Further research could be look at rate of respiration of organism as metabolism involves generating and releasing energy. Metabolic reaction includes the interaction with water and need ATP to generate energy. Thus, rate of oxygen consumption can be used to measure metabolic rates⁸.

CONCLUSION

Based on the result obtained from experiment and statistical analysis, it can be concluded that the higher the temperature, the higher the metabolic rate of organism. *Lucilia sericata* larvae is chosen to represent the other organism because it is a simple organism with short life cycle and can react towards different temperatures significantly.

SOURCE EVALUATION

A range of sources has been selected to use in this research. Source 1 is a scientific journal article from American Physiology Society that publishes only highly regarded journals that meets the demands of research investigators, educators and for those who are interested in the physiological sciences. Source 4 and 6 could be regarded as a reliable journal as it is published from a well-established department.

Source 2 and 5 is a published book from experienced authors, thus the information is reliable. This book explains the basic principles of enzymes and metabolic control based on investigations and research. Source 3 is a statistical biology book that published from Michigan University thus the information is very reliable.

Wikipedia (source 7, 10 and 12) is a free online encyclopedia that provides million articles and reliable information as it is continually updated and improved from time to time. Source 9 is a website that provides readers with scientific ideas. The expertise writers focus on creating valuable information, thus the facts should be trustable and do not contain any biased viewpoints.

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