Investigating Cellular Respiration Using Vernier Sensors

INTRODUCTION

Cell respiration refers to the process of converting the chemical energy of organic molecules into a form immediately usable by organisms. Glucose may be oxidized completely if sufficient oxygen is available by the following equation:

$$C_6H_{12}O_6 + 6\ O_2(g) \rightarrow 6\ H_2O + 6\ CO_2(g) + \text{energy}$$

All organisms, including plants and animals, oxidize glucose for energy. Often, this energy is used to convert ADP and phosphate into ATP. It is known that peas undergo cell respiration during germination.

In Procedure 1, you will use a CO_2 Gas Sensor to determine the respiration rate of peas.

PROCEDURE 1

1. If your CO_2 Gas Sensor has a switch, set it to the Low (0–10,000 ppm) setting. Connect the CO_2 Gas Sensor to the data-collection interface.

2. Start the data-collection program. Allow 90 seconds for the sensor to warm up.

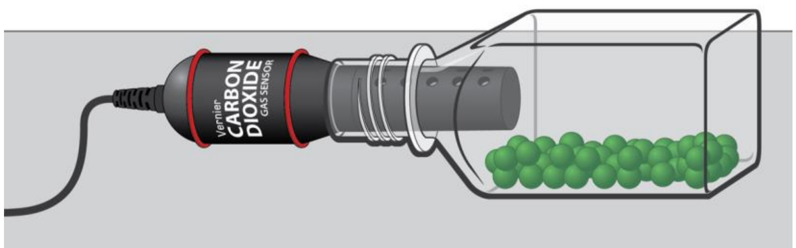


Figure 1

3. Prepare the peas for data collection.
   a. Obtain 25 germinating peas and blot them dry with a paper towel.
   b. Determine and record the mass of the peas.
   c. Place the peas in the respiration chamber.
   d. Place the shaft of the CO_2 Gas Sensor in the opening of the respiration chamber and lay flat, as shown in Figure 1.

Very Important: Do not place the sensor directly into any liquid. The sensor is intended only for measuring gaseous, not aqueous, CO_2 concentration.

4. Pause 60 seconds, and then start data collection. Data will be collected for 600 seconds.

5. When data collection has finished, remove the CO_2 Gas Sensor from the respiration chamber. Return the peas to the designated location. Rinse the respiration chamber with water and then empty it. Repeat this rinsing procedure two more times. Thoroughly dry the inside of the chamber with a paper towel.

6. Use the linear regression function to determine the respiration rate, which is the slope of the line, *m*. **Record the respiration rate in ppm CO_2 s^{-1}.**

PROCEDURE 1 QUESTIONS

1. Use the respiration rate determined in Step 5, in CO_2 ppm/s, and the mass of your peas determined in Step 3, in grams, to determine the normalized respiration rate per gram of peas (ppm CO_2 s^{-1} g^{-1}).

2. Do the results of this investigation verify that germinating peas respire? How do you know?

3. What do you expect would happen to the rate of respiration if you repeated this investigation with non-germinating peas?

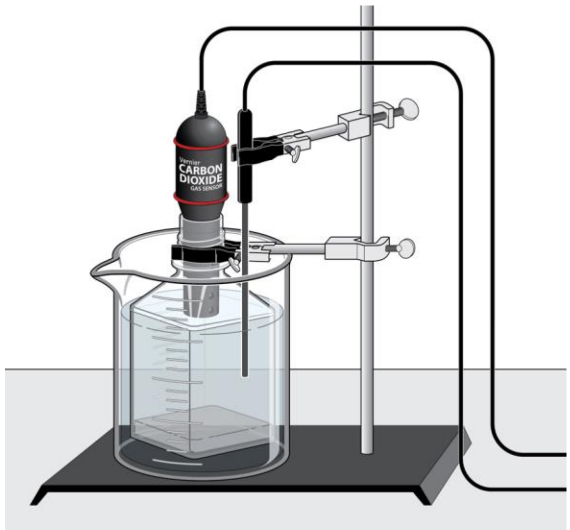
4. Repeat the experiment from Procedure 1 using non-germinating peas and record your respiration rate in ppm CO_2 s^{-1} g^{-1}.

5. Based on your experimental results, do nongerminating peas undergo cell respiration?

6. List three factors that could possibly affect cell respiration rates in germinating and/or nongerminating peas.

PROCEDURE 2. SUGAR METABOLISM IN YEAST

Yeast are able to metabolize some foods, but not others. In order for an organism to make use of a potential source of food, it must be capable of transporting the food into its cells. It must also have the proper enzymes capable of breaking the food's chemical bonds in a useful way. Sugars are vital to all living organisms. Yeast are capable of using some, but not all sugars as a food source. Yeast can metabolize sugar in two ways, *aerobically*, with the aid of oxygen, or *anaerobically*, without oxygen. In both cases, carbon dioxide, CO_2, is produced. The rate that this gas is produced is referred to as the rate of respiration.



In Procedure 2, you will use a CO_2 Gas Sensor to determine the rate of respiration of glucose by yeast.

1. Set up the sensors.
   a. If your CO_2 Gas Sensor has a switch, set it to the Low (0–10,000 ppm) setting. Connect the CO_2 Gas Sensor to the data-collection interface.
   b. Connect the Temperature Probe to the data-collection interface.
   c. Start the data-collection program.
   d. Set the data-collection duration to 15 minutes and the data-collection rate to 10 samples/minute.
2. Prepare a 30°C water bath. A water bath is simply a large beaker of water at a certain temperature. This ensures that the respiration reaction will occur at a constant and controlled temperature.
   a. Fill a 1000 mL beaker with about 600 mL of water.
   b. Use a utility clamp to affix the Temperature Probe to a ring stand and suspend the Temperature Probe in the water bath.
   c. Heat water bath until it reaches 30°C. Monitor and adjust temperature to ensure it is 30°C throughout the duration of the experiment.
3. Collect data.
   a. Pipet 1.0 mL of yeast suspension into a 250 mL respiration chamber. **Important**: The yeast suspension must be removed from the middle of a yeast source that is being stirred by a magnetic stirrer at a constant stirring speed.

b. Pipet 1.0 mL of a 0.3M glucose solution into the respiration chamber.
c. Swirl the glucose-yeast mixture for five seconds to ensure thorough mixing.
d. Using a gentle twisting motion, quickly place the shaft of the CO2 Gas Sensor into the opening of the respiration chamber.
e. Immerse the respiration chamber into the water bath and fasten it in position with a utility clamp. You will need to temporarily raise the Temperature Probe above the water bath in order to accommodate the respiration chamber and its utility clamp.
f. Start data collection.
g. Data collection will end after 15 minutes.

4. When data collection has finished, remove the CO_2 Gas Sensor from the respiration chamber. Rinse the respiration chamber with water and then empty it. Repeat this rinsing procedure two more times. Make sure that all yeast have been removed. Thoroughly dry the inside of the chamber with a paper towel.

PROCEDURE 2 QUESTIONS

1. During the initial minutes of the data-collection period, the glucose and yeast mixture warmed to the temperature of the water bath. The glucose was transported across the membrane of the yeast cells where enzymes began catalyzing the metabolism of glucose, which produces CO_2 gas. This process takes time to happen. Accordingly, the first ten minutes of the data-collection period will not be used to determine the respiration rate.

   Perform a linear fit on the 10–15 minute portion of the graph. Record the slope of the line, *m*, as the respiration rate (in ppm/min).

2. List three common sugars, other than glucose, that you think may also metabolized by yeast.

3. List three factors that could possibly affect respiration rates of sugars by yeast.

PROCEDURE 3. GUIDED INQUIRY EXPERIMENT

In this third and final procedure, your group will design and perform an experiment to answer the question: *"How do respiration rates of yeast exposed to various sugars compare?"*
Through this experiment, you will

- Identify variables, design and perform the experiment, collect data, analyze data, draw a conclusion, and formulate a knowledge claim based on evidence from the experiment.
- Obtain graphic representations of respiration rate.
- Determine respiration rate by yeast while using different sugars.
- Determine which sugars can be used as a food source by yeast.

Follow the framework below to plan and execute your experiment, filling in notes where indicated.

A. Planning the experiment

During the planning phase, we will formulate a hypothesis, determine the experimental design and setup, and write the methods that will be used to collect data.

Forming a Hypothesis. A hypothesis is a tentative, testable answer to a scientific question. In order to form an appropriate hypothesis, you may need to conduct some preliminary research on the topic. Information may be gathered from resources at hand including your lab manual, textbook, and/or online resources. If needed, take a few minutes to gather information on the research topic so that you can form a good hypothesis.

Each group will write a hypothesis to potentially answer the research question "*How do respiration rates of yeast exposed to various sugars compare?"*. Write your hypothesis below.

My group's proposed hypothesis:

As a class, we will discuss each hypothesis and decides which one(s) will be tested. Write the hypothesis that will be tested by your group in the space below.

The hypothesis that my group will be testing:

Now that you have formed a hypothesis, it is time to create the plan for how it will be tested. In the spaces provided below, write the materials and methods that will be used to execute the plan. This should be written in step-by-step fashion and include enough detail that someone could replicate the experiment.

Materials and methods:

B. Carrying out the plan

Before you start the experiment, check with your instructor to ensure your plan is feasible. Once you have your instructor's approval, you may carry out the plan. As you conduct the experiment, take note of any procedural adjustments that need to be made as well as anything else noteworthy.

C. Collecting and organizing the data

Experimental data will be collected using the Vernier Lab Quest devices. As in Procedures 1 & 2, generate a graph for each trial of your experiment. Determine yeast respiration rates (in ppm CO_2 s^{-1}) for each trial. Organize this data in a table in the space below.

D. Forming a conclusion

Write a conclusion based on your results.

E. Assignment

Each student will report their group's findings in the form of a short lab report. The lab report should include the following

- Introduction including relevant background info., purpose, and hypothesis
- Materials and methods written in paragraph form (no lists)
- Results including a written description and table (see C. above)
- Discussion of results including whether or not your hypothesis was met and why, and any potential sources of error.
- Conclusion
- Any new research questions that have emerged as a result of your experimental findings