

Anaerobic respiration in yeast

investigate the role of anaerobic respiration by yeast in different conditions

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. Teacher answers start on a new page.

Name

Date

Aim

To investigate how temperature affects the rate of anaerobic respiration in yeast, by measuring the volume of carbon dioxide produced.

Background

Yeast is a single-celled fungus. When it has no oxygen it respire **anaerobically**, releasing energy from glucose without using oxygen: glucose → ethanol + carbon dioxide. This process is called **fermentation**. Yeast is used in baking and brewing.

The rate of anaerobic respiration can be found from the volume of **carbon dioxide** produced in a set time. Carbon dioxide turns limewater cloudy, which confirms what the gas is.

The reactions of respiration are controlled by enzymes. As the temperature rises the enzymes work faster, until the optimum temperature, which is usually about 35–40 °C for yeast. At higher temperatures the enzymes are **denatured**, because their shape changes, and the rate falls.

To make the yeast respire anaerobically, the sugar solution is boiled and cooled to remove dissolved oxygen, and a layer of oil on top stops oxygen getting back in. The same method can be used with different sugars or sugar concentrations as the independent variable.

Hypothesis

The volume of carbon dioxide produced in 5 minutes will increase as the temperature rises to about 40 °C and then fall at higher temperatures, because enzymes work faster up to their optimum and are denatured above it.

Variables

Independent	Temperature of the water bath (20, 30, 40, 50 and 60 °C)
Dependent	Volume of carbon dioxide collected in 5 minutes (cm ³), used to calculate the rate (cm ³ /min)
Control	• Mass of yeast (1 g) • Volume and concentration of sugar solution (20 cm³ of 5% glucose) • Type of sugar (glucose) • Volume of oil (a 1 cm layer) • Time allowed for each reading (5 minutes)

Equipment

- Dried yeast (1 g for each run)
- 5% glucose solution (20 cm³ for each run)
- Boiling tubes (one for each run) and bungs with delivery tubes
- 50 cm³ gas syringe

- Vegetable oil
- 250 cm³ beaker for a water bath, kettle and cold water (or a thermostatically controlled water bath)
- Thermometer
- Bunsen burner, tripod, gauze and heatproof mat, to boil the glucose solution
- Stopwatch
- Measuring cylinder, 25 cm³
- Stirring rod, balance and spatula
- Eye protection
- Limewater and a test tube (to confirm the gas)

Risk assessment

Hazard	Risk	Precaution
Hot water	Scalds when filling the water bath or from the 60 °C bath	Use a heatproof mat, handle the kettle carefully and do not carry hot water across the room.
Boiling the glucose solution	Scalds from the hot liquid	Cool the solution before it is used, and wear eye protection.
Glass syringe and glass tubes	Cuts if broken	Handle carefully, hold the bung when fitting the delivery tube and tell the teacher about any breakage.
Limewater (irritant to eyes)	Eye irritation from splashes	Wear eye protection; wash splashes off skin with water.
Spilt oil or water	Slipping	Mop up spills straight away. Wash hands after handling the yeast.

Method

1. Boil some 5% glucose solution to remove dissolved oxygen and allow it to cool in a covered container.
2. Set up a water bath in a 250 cm³ beaker at 20 °C using cold water and hot water from the kettle, and check it with a thermometer.
3. Measure 20 cm³ of the cooled glucose solution into a boiling tube and stand it in the water bath for 5 minutes so that it reaches the temperature of the bath.
4. Weigh 1 g of dried yeast and add it to the glucose solution. Stir to mix.
5. Gently pour a 1 cm layer of vegetable oil on top of the mixture. This stops oxygen getting in, so the yeast respire anaerobically.
6. Put the bung and delivery tube in the boiling tube and leave it in the water bath for 5 minutes, so that the dried yeast becomes active and the mixture is at the bath temperature. Then connect the delivery tube to the gas syringe, with the plunger pushed fully in, and start the stopwatch.
7. Keep the water bath at the same temperature, adding hot or cold water if needed.
8. After 5 minutes, read the volume of gas in the syringe, in cm³, and record it.
9. Repeat steps 3 to 8 with a new tube of yeast at 30, 40, 50 and 60 °C.
10. Repeat the whole investigation twice more, so that each temperature has three runs.
11. Calculate the mean volume at each temperature, and the rate in cm³/min (mean volume ÷ 5).
12. To confirm the gas, connect the delivery tube from a fresh mixture to a test tube of limewater and observe the limewater turning cloudy. Wash your hands.

Results

Results table: carbon dioxide collected in 5 minutes					
Temperature (°C)	Volume of gas, run 1 (cm³)	Volume of gas, run 2 (cm³)	Volume of gas, run 3 (cm³)	Mean volume (cm³)	Rate of gas production (cm³/min)
20					
30					
40					
50					
60					

Graph

Line graph with temperature (°C) on the x-axis and rate of gas production (cm³/min) on the y-axis, starting at 0. Plot the points and join them with a smooth curve (or straight lines between points). Identify the optimum temperature at the peak.



Exam questions 10 questions · 26 marks

1 State the independent variable and the dependent variable in this investigation. [2 marks]

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2 A layer of oil was added to the top of the yeast and glucose mixture. Explain why. **[2 marks]**

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3 The glucose solution was boiled and then cooled before the yeast was added. Explain why it was boiled and why it was cooled. **[2 marks]**

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4 Write the word equation for anaerobic respiration in yeast. **[2 marks]**

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5 In three runs at 30 °C the volumes of gas collected in 5 minutes were 11 cm³, 12 cm³ and 13 cm³. Calculate the mean rate of gas production in cm³/min. **[2 marks]**

Answer =

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6 Very little gas was collected at 60 °C. Explain why. **[3 marks]**

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7 Describe how you could show that the gas given off by the yeast is carbon dioxide. **[2 marks]**

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8 A student counted bubbles from the delivery tube instead of using a gas syringe. Explain why the gas syringe gives more accurate results. **[2 marks]**

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9 Describe how the method could be changed to investigate the effect of the concentration of glucose on the rate of anaerobic respiration. **[3 marks]**

[illegible]

10 Describe an investigation to find the effect of temperature on the rate of anaerobic respiration in yeast. Include how you would make the results reliable. **[6 marks]**

[illegible]

Teacher answers

Practical 14: Anaerobic respiration in yeast. The example results are practice data, not real measurements.

Example results

Example results (practice data)					
Temperature (°C)	Volume of gas, run 1 (cm ³)	Volume of gas, run 2 (cm ³)	Volume of gas, run 3 (cm ³)	Mean volume (cm ³)	Rate of gas production (cm ³ /min)
20	4	5	3	4.0	0.8
30	11	12	13	12.0	2.4
40	20	22	21	21.0	4.2
50	9	8	10	9.0	1.8
60	1	0	2	1.0	0.2

Conclusion

In the example results the rate of carbon dioxide production increased from 0.8 cm³/min at 20 °C to a maximum of 4.2 cm³/min at 40 °C and then fell to 0.2 cm³/min at 60 °C. This supports the hypothesis. As the temperature rises the enzymes in yeast that control anaerobic respiration have more kinetic energy and collide with their substrate more often, so the rate increases. Above the optimum temperature the enzymes start to be denatured, because their active sites change shape and the substrate no longer fits, so the rate decreases, and at 60 °C most of the yeast is killed. The optimum temperature was about 40 °C, but testing at smaller intervals (35 °C and 45 °C) would give a better estimate.

Errors and improvements

Error	Effect on the results	Improvement
The mixture takes time to reach the water bath temperature, or the bath temperature changes during the 5 minutes (systematic error)	The yeast is not at the planned temperature, so the rate is affected	Warm the glucose solution in the bath for 5 minutes before adding yeast, use a lid or insulation, and keep checking the thermometer.
Oxygen is still present, for example from dissolved oxygen in the solution or air in the tube, so the yeast is not respiring only anaerobically	The yeast is not respiring only anaerobically, so the results do not show the rate of anaerobic respiration alone	Boil and cool the solution, make sure the oil layer is complete and the bung is airtight.
Carbon dioxide dissolves in the solution and gas leaks from the apparatus or the syringe sticks	The volume of gas collected is less than the amount made, especially at low temperatures	Check the seals, lightly lubricate the syringe and use the same method at every temperature.
Random variation between runs, for example in the mass of yeast or how well it is mixed	Results are not repeatable, and a mean may hide anomalies	Repeat each temperature at least three times, weigh the yeast carefully and use a mean, ignoring any anomalies.
Temperature intervals of 10 °C are large	The optimum is not found accurately	Test smaller intervals around the peak, for example 35, 40 and 45 °C.

Mark scheme

One mark for each point unless a maximum is given. Words in brackets are not needed for the mark.

1. [2]

- independent variable: temperature (of the water bath) (1)
- dependent variable: volume of carbon dioxide (gas) collected in a set time (1)

2. [2]

- to stop oxygen from the air getting into the mixture (1)
- so that the yeast respires anaerobically (1)

3. [2]

- boiling removes dissolved oxygen (1)
- cooling so that the hot solution does not kill the yeast (1)

4. [2]

- glucose → ethanol (alcohol) (1)
- + carbon dioxide (1)

5. [2]

- $(11 + 12 + 13) \div 3 = 12 \text{ cm}^3$ (1)
- $12 \div 5 = 2.4 \text{ cm}^3/\text{min}$ (1)

6. [3]

- the enzymes (in the yeast) are denatured at this temperature (1)
- the shape of the active site changes so the substrate no longer fits (1)
- so respiration is slower / the yeast is killed (1)

7. [2]

- bubble the gas through limewater (1)
- it turns cloudy (milky) (1)

8. [2]

- bubbles can be different sizes (1)
- the syringe measures the actual volume of gas (1)

9. [3]

- use different concentrations of glucose solution, for example 1%, 2%, 5% and 10% (1)
- keep the temperature (for example 35 °C) the same, and the volume of solution, mass of yeast and time (1)
- measure the volume of gas in a set time and calculate the rate (1)

10. [6]

Level 3 5-6	A clear, ordered method with a range of temperatures, anaerobic conditions, a way of measuring the gas and several control variables, and repeats with a mean to give reliable results
Level 2 3-4	A method with several temperatures and a way of measuring the rate, but with some detail, control or ordering missing
Level 1 1-2	A simple or partial method, for example yeast and sugar at different temperatures with little detail

Indicative content

- yeast and glucose solution in a boiling tube in water baths at different temperatures, for example 20, 30, 40, 50 and 60 °C
- oil layer to keep it anaerobic
- delivery tube to a gas syringe to measure the volume of carbon dioxide in a set time, for example 5 minutes
- keep the mass of yeast, volume and concentration of glucose, and time the same
- repeat each temperature at least three times and calculate a mean
- calculate the rate (cm^3/min) and plot a graph of rate against temperature

Exam tips

- Know why each step is there: boiled and cooled sugar solution and the oil layer both make sure the yeast respires without oxygen.
- At high temperatures say the enzymes are denatured, because the shape of the active site changes. Do not say the enzymes are killed.
- Name the control variables and say how they are kept the same, for example 1 g of yeast and 20 cm^3 of 5% glucose.
- Measure the gas in a fixed time so you can calculate a rate. A gas syringe is more accurate than counting bubbles, because bubbles can be different sizes.
- The products are ethanol and carbon dioxide (not lactic acid, which is produced in animal muscle).