

Temperature and respiration in yeast

Investigate and describe the effect of temperature on respiration in yeast

For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). Teacher answers start on a new page.

Name

Date

Aim

To investigate how temperature affects the rate of respiration in yeast by counting the bubbles of carbon dioxide released in 2 minutes.

Background

Yeast is a single-celled fungus. Yeast cells respire glucose to release energy, and carbon dioxide is one of the products. The rate at which carbon dioxide is produced shows the rate of respiration.

Respiration is controlled by enzymes. As the temperature increases the reaction becomes faster, up to the **optimum temperature**. Above the optimum, the enzymes are **denatured**, so respiration slows and then stops.

In this investigation the yeast is in a solution of glucose, which is its source of energy. The carbon dioxide is shown by bubbles from a delivery tube, and it can be identified using limewater, which turns cloudy.

Hypothesis

The rate of respiration in yeast will increase as temperature increases up to an optimum temperature, and then decrease, because the enzymes are denatured at high temperatures.

Variables

Independent	Temperature of the water bath (10, 20, 30, 40, 50 and 60 °C)
Dependent	The number of bubbles of carbon dioxide produced in 2 minutes, used to calculate the rate in bubbles per min
Control	• The same volume (5 cm³) of the same well-stirred yeast suspension in each tube • The same volume (10 cm³) and concentration (10%) of glucose solution • The same time for counting bubbles (2 minutes) after the same waiting time • The same size of boiling tube and delivery tube, and the same depth of the delivery tube end under the water • The same time (5 minutes) for the yeast suspension and the glucose solution to reach the water bath temperature before mixing

Equipment

- Yeast suspension (dried yeast mixed with water, about 1 g in 10 cm³), made up by the technician at least 15 minutes before the lesson
- 10% glucose solution
- 6 boiling tubes (large test-tubes, 150 mm × 25 mm), each with a bung and delivery tube
- 6 standard test-tubes for 5 cm³ portions of yeast suspension
- 6 test-tubes of water to collect bubbles

- 250 cm³ beakers as water baths, or thermostatically controlled water baths
- Hot water from a kettle, cold water and ice
- Thermometers, -10 °C to +110 °C
- Measuring cylinders, 10 cm³, or 10 cm³ syringes
- Stop-clock reading to 1 s or better
- Test-tube racks, and a marker pen for glassware
- Limewater (to identify the gas)
- Eye protection

Risk assessment

Hazard	Risk	Precaution
Hot water up to 60 °C	Scalds.	Do not use water hotter than 60 °C. Stand the beakers on a stable bench, pour hot water carefully and wipe up spills at once.
Glassware	Cuts if broken.	Handle with care and report any breakage.
Yeast suspension	Low hazard; dried yeast powder may cause an allergic reaction in a few people.	Avoid breathing in the dry powder and wash hands afterwards.
Limewater	Irritates the eyes.	Wear eye protection.

Method

1. Put on eye protection. Label six boiling tubes and six test-tubes with the temperatures 10, 20, 30, 40, 50 and 60 °C.
2. Use a measuring cylinder to put 10 cm³ of glucose solution into each boiling tube.
3. Stir the yeast suspension and put 5 cm³ of it into each labelled test-tube.
4. Set up a water bath in a beaker for each temperature. Use a thermometer to check it, adding hot water or ice to adjust it.
5. Stand each boiling tube of glucose and its test-tube of yeast in the matching water bath for 5 minutes, so that both reach the temperature of the bath.
6. Pour the yeast into the glucose solution in the first boiling tube. Fit the bung and delivery tube straight away and put the end of the delivery tube under the water in a test-tube.
7. Wait 2 minutes for the bubbling to become steady, then start the stop-clock.
8. Count the number of bubbles of gas that come from the delivery tube in 2 minutes. Record the number.
9. Repeat steps 6 to 8 at each of the other temperatures. Check each water bath with the thermometer and add hot water or ice to keep it at the right temperature.
10. Repeat the whole investigation twice more, using fresh solutions, so that you have three readings at each temperature.
11. Calculate the mean number of bubbles in 2 minutes for each temperature, then the rate using: rate = mean number of bubbles ÷ 2.
12. To identify the gas, lead the delivery tube from the 30 °C or 40 °C tube into limewater instead of water and observe that the limewater turns cloudy.
13. Plot a graph of rate against temperature.

Results

Number of bubbles of carbon dioxide produced in 2 minutes					
temperature / °C	number of bubbles in 2 min: 1	number of bubbles in 2 min: 2	number of bubbles in 2 min: 3	mean number of bubbles in 2 min	rate / bubbles per min
10					
20					
30					
40					
50					
60					

Graph

A line graph with temperature / °C on the x-axis (0 to 60) and rate / bubbles per min on the y-axis. Plot the six points as small crosses (x) and draw a single smooth curve of best fit, which should rise to a peak and then fall. Use a scale so that more than half of the grid is used in both directions. Read the optimum temperature from the highest point of the curve.



Exam questions 10 questions · 26 marks

1 Name the gas given off by the yeast and state how you could show that it is this gas. **[2 marks]**

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2 A student investigates the effect of temperature on respiration in yeast. (a) State the independent variable. [1] (b) State the dependent variable. [1] (c) State one variable that must be kept constant. [1] **[3 marks]**

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3 At 30 °C the student counted 48, 52 and 50 bubbles in 2 minutes. Calculate the rate in bubbles per min. Show your working. **[3 marks]**

Answer =

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- 4** The table shows the rate of bubbles at each temperature. Describe and explain the pattern in the results. **[4 marks]**

Rate of bubbles at different temperatures	
temperature / °C	rate / bubbles per min
10	3.5
20	11.0
30	25.0
40	32.0
50	8.0
60	0.0

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- 5** The glucose solution and the yeast suspension are left in the water bath for 5 minutes before they are mixed. Explain why. **[2 marks]**

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- 6** Describe a control experiment for this investigation and state the result expected. **[2 marks]**

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- 7** Counting bubbles is not a very accurate way to measure the rate of respiration. Explain why, and suggest a better way to measure it. **[3 marks]**

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8 Describe two safety precautions for this investigation. **[2 marks]**

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9 The student wants to find the optimum temperature more precisely. Suggest what the student should do. **[2 marks]**

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10 Describe how the results should be presented as a graph. **[3 marks]**

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Teacher answers

Practical skill 13: Temperature and respiration in yeast. The example results are practice data, not real measurements.

Example results

Example results (practice data)					
temperature / °C	number of bubbles in 2 min: 1	number of bubbles in 2 min: 2	number of bubbles in 2 min: 3	mean number of bubbles in 2 min	rate / bubbles per min
10	6	8	7	7	3.5
20	22	25	19	22	11.0
30	48	52	50	50	25.0
40	66	62	64	64	32.0
50	18	15	15	16	8.0
60	0	0	0	0	0.0

Conclusion

The rate of respiration in yeast increased as the temperature rose from 10 °C (3.5 bubbles per min) to a maximum at 40 °C (32.0 bubbles per min). At 50 °C the rate fell to 8.0 bubbles per min, and at 60 °C no bubbles were produced. This supports the hypothesis. Respiration is controlled by enzymes. As the temperature rises the rate increases, up to the optimum temperature, which is about 40 °C in these results. Above the optimum the enzymes in the yeast are denatured, so respiration slows and then stops. Supplement: at low temperatures the enzyme and substrate molecules have less kinetic energy, so they collide less often; at high temperatures the shape of the active site changes. The gas released is carbon dioxide, because it turns limewater cloudy.

Errors and improvements

Error	Effect on the results	Improvement
Bubbles are different sizes, so counting bubbles does not measure the volume of gas.	The count may not match the true rate of carbon dioxide production, and the results are less accurate.	Collect the gas in an inverted measuring cylinder or gas syringe and measure its volume in cm ³ .
Bubbles are counted by eye and some are missed when bubbling is fast.	Random errors in the count, mostly at the highest rates.	Repeat three times and calculate a mean, or measure the volume of gas instead.
The yeast and glucose are not at the water bath temperature when mixed, or the water bath cools during the count.	The yeast respires at a different temperature from the one recorded.	Leave both solutions in the water bath for 5 minutes before mixing, and check and adjust the bath temperature during the count, or use a thermostatically controlled water bath.
The yeast suspension settles, so each tube gets a different mass of yeast.	Different numbers of yeast cells give different rates.	Stir the suspension each time before measuring it out.
When the bung is first fitted, the gas made first dissolves in the solution and fills the air space above it, so bubbling starts slowly and unevenly.	A count started straight away is too low and does not show the steady rate.	Wait 2 minutes, until the bubbling is steady, before starting the count.

Mark scheme

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

1. [2]

- carbon dioxide (1) allow CO₂
- bubble it through limewater, which turns cloudy / milky (1)

2. [3]

- (a) temperature (1)
- (b) number of bubbles (of gas) in a set time (1) allow rate of carbon dioxide production
- (c) any one from: volume / mass of yeast / volume of glucose solution / concentration of glucose solution / time for counting / size of tube (1) ignore 'amount' unqualified

3. [3]

- mean = $(48 + 52 + 50) \div 3 = 50$ (1)
- $50 \div 2$ (1)
- 25 bubbles per min (1) unit required; allow 25.0

4. [4]

- the rate increases as the temperature rises from 10 °C to 40 °C (1)
- highest rate / optimum at (about) 40 °C (1)
- the rate falls at 50 °C and is zero at 60 °C (1)
- (above the optimum) enzymes are denatured, so respiration slows / stops (1) reject enzymes are killed

5. [2]

- so that they reach the temperature of the water bath (1)
- so that the yeast respires at the stated temperature from the start / so the temperature is the only variable changed (1)

6. [2]

- use boiled (and cooled) yeast in glucose solution in place of the live yeast (1) allow glucose solution with water in place of yeast
- no bubbles / no gas produced (1)

7. [3]

- bubbles may be different sizes / do not all contain the same volume of gas (1)
- collect the gas in a gas syringe / an upturned measuring cylinder full of water (1)
- measure the volume of gas produced in a set time (in cm³) (1)

8. [2]

- wear eye protection (1)
- do not use water hotter than 60 °C / take care with hot water to avoid scalds (1)
- handle glassware carefully / wipe up spills (1)
- Max 2

9. [2]

- use smaller temperature intervals, e.g. every 2 °C or 5 °C (1)
- between 30 °C and 50 °C / around 40 °C (1)

10. [3]

- temperature / °C on the x-axis and rate / bubbles per min on the y-axis (1)
- suitable scales using more than half the grid, points plotted as small crosses (1)
- a single smooth curve of best fit (1) reject joining dot to dot with a ruler

Exam tips

- Yeast respires glucose and releases carbon dioxide. Identify the gas with limewater, which turns cloudy.
- The rate rises to an optimum and then falls because the enzymes are denatured. Do not say that the enzymes are killed, because enzymes are not alive.
- Name controls specifically: the same mass of yeast, the same volume and concentration of glucose solution, and the same time for counting.
- For a control experiment use boiled yeast, which should produce no bubbles.
- Rate = number of bubbles ÷ time. Show the working and give the unit, for example bubbles per min.