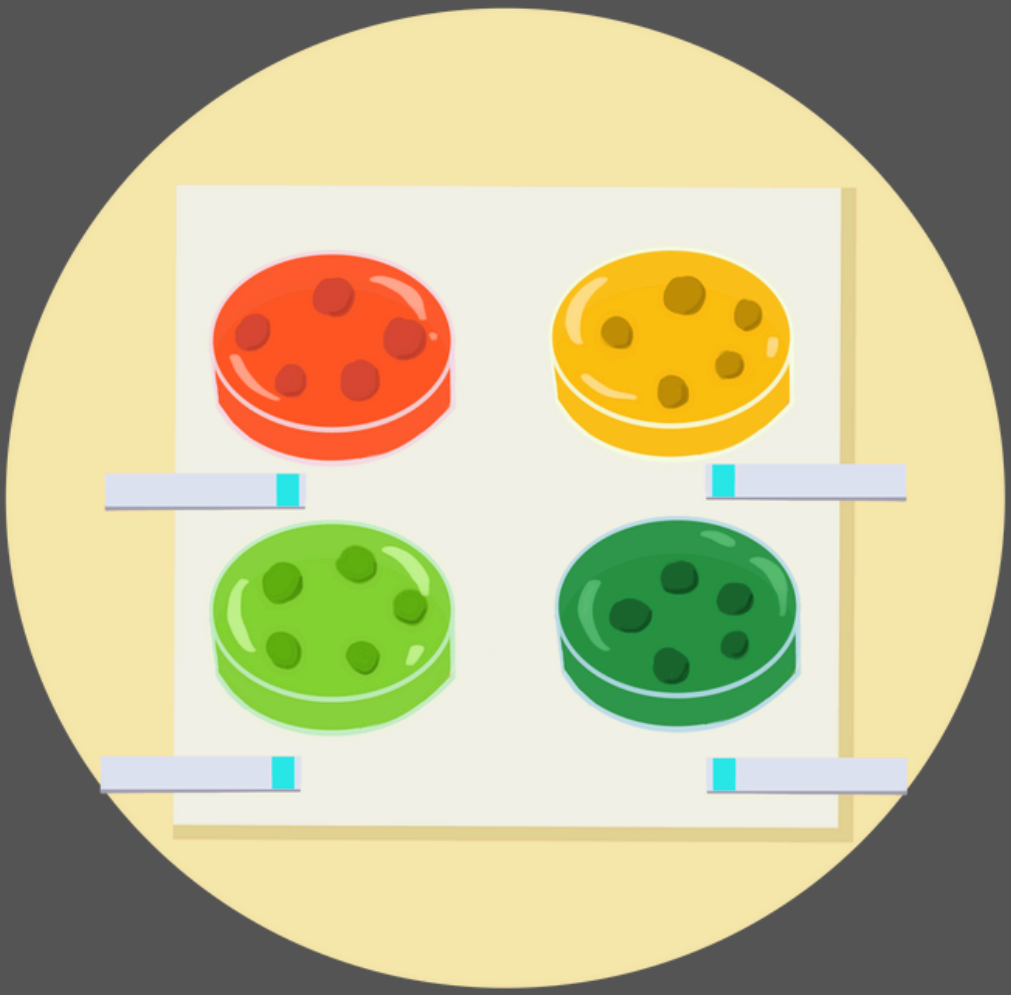
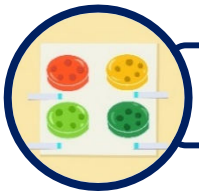
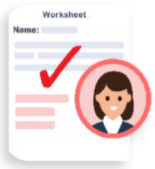


Yeast Bead Invertase Investigation



Yeast Bead Invertase Investigation

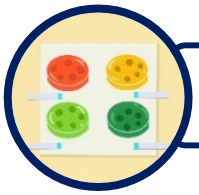
Table of Content



Notes for teachers

- Scan the QR code to get the electronic files.
- Teachers are strongly encouraged to adapt and modify these resources as necessary.

Innovations in Biology Investigations



Yeast Bead Invertase Investigation

Overview

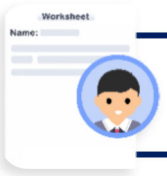
- The *Yeast Bead Invertase Investigation* is about the industrial application of immobilised yeasts for the production of invert syrup.
- Immobilised yeasts, known as yeast beads, contain invertase (Bryer, 2016).
- Students investigate the effect of pH on the activity of yeast bead invertase.
- Students collect semi-quantitative data (i.e. the colour intensity of glucose test strips) to determine the invertase activity.
- Students are given the opportunity to design and carry out an experiment and assess the accuracy of the measurement tool, and the reliability of the data.

Teaching Plan

Prerequisite knowledge (scientific ideas)

- Properties, actions, and roles of enzymes
- Factors that affect the actions of enzymes

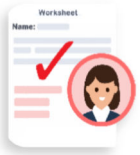
Lesson	Lesson sequence	Duration (mins)	Resources
Stage ❶ Preparing for the investigation • It is situated in an authentic context related to the industrial application of invertase in chocolate making (**Contextualisation**). • Students read information to familiarise themselves with the background of the investigation (*Reading Materials*).			
Before Lesson 1	• The teacher distributes *Worksheet 1* for students to complete at home so that they can be familiar with the background of the investigation.		*Worksheet 1*
1	• The teacher discusses the investigation context with students. • The teacher provides feedback on students' responses in *Worksheet 1*.	40	Student Samples 1
Stage ❷ Designing the investigation • Students interact with a virtual laboratory to familiarise themselves with the materials and apparatuses they use in the investigation (*Virtual Laboratory*). • Students use a template to design their own experimental set-ups (*Investigation Planning Template*). • Students have the chance to evaluate their own and their peers' experimental set-ups (*Self & Peer Evaluation*).			
2	• The teacher presents the main investigation context and discusses with students questions related to their experimental designs. • The teacher provides students with the laboratory manual for preparation at home.	40	Teacher Notes 1
Stage ❸ Carrying out the investigation • Students collect data using a template (*Data Collection Sheet*).			
3	• Teacher asks questions to help students connect their lab experience and related ideas/scientific inquiry skills. • Students carry out the investigation.	40	Laboratory Manual
Stage ❹ Explaining and evaluating data • Students assess the limitations of the data collected in answering the investigation question.			
Before Lesson 4	• Students complete data reporting and analysis at home. • The teacher collects and marks student responses.		Teacher Notes 2
4	• The teacher provides feedback on students' performance related to data reporting and analysis.	40	Teacher Notes 2



Instructional Materials

Stage 1 Preparing for the investigation

Student Worksheet 1



Notes for teachers

- Teachers can distribute *Worksheet 1* and ask students to read the background information related to the investigation and design their experimental set-ups at home.
- Teachers can collect students' drawing using a *Google Form.*
- Scan the QR code to get a copy of the *Google Form*.

Task 1

- Read the scenario and answer the questions that follow:

Scenario

Invertase is an enzyme that catalyses the breakdown of sucrose into fructose and glucose. It is widely used in the food industry to produce creams, jams, and artificial honey.

Yeast (*Saccharomyces cerevisiae*) is a rich source of invertase. Yeast cells are immobilised to form yeast beads, which can be easily removed from the sucrose solution and reused.

In this investigation, you will study yeast bead invertase. Read the information in the *Data File* to familiarise yourself with the background of this investigation. You will use your biological knowledge of enzymes and the design of valid and reliable experiments to complete this investigation.

Question

1. You have found that you can control the time for making invert sugar syrup by changing the temperature during the making of invert sugar syrup. Therefore, you want to investigate the effects of temperature on the activity of yeast bead invertase.

The virtual laboratory provides students with opportunities to get familiar with materials used in the investigation.

- You have been provided with the following materials:

20% Sucrose solution	Water bath	Plastic dropper
Yeast beads	Glucose test strips	Thermometer
Timer	Vials	Forceps
Measuring cylinder	Spotting plate	Colour chart
White tile	Spoon	

- You may also make use of other common apparatuses in the laboratory.

Scan the QR code to see the materials

(a) Briefly describe how you would use the above materials to plan an experiment to achieve the aim of the investigation.

- You can draw your experimental design.
- Write down any important experimental design decisions
- The *Investigation Planning Chart* (scan the QR code) can help you with this.

Data File

Your biology teacher asks you to read the following source materials to prepare for planning a scientific investigation on yeast bead invertase:

Source 1: Industrial application of invertase

Invertase is an enzyme that catalyses the breakdown of sucrose into fructose and glucose.

$$\text{sucrose} \xrightarrow{\text{invertase}} \text{fructose} + \text{glucose}$$

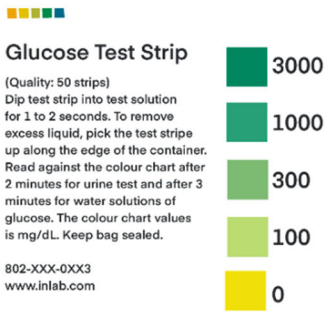
Invertase is commonly used in the food industry to produce 'invert syrup' from sucrose solutions. Invert syrup contains a mixture of fructose and glucose from sucrose treated with invertase. The products formed in the enzyme reaction (i.e., fructose and glucose) have a higher solubility than the substrate (i.e., sucrose).

A well-known use of invertase is in the production of chocolates with a soft centre, such as *Lindt Lindor* milk chocolate truffles. One way to make this type of chocolate is to add a small amount of invertase to the solid sugar filling, which consists of table sugar (sucrose). The mixture of fructose and glucose from the sucrose treated with invertase becomes liquid in the chocolate shell.

Scan the QR code to learn more about how invertase is used in the food industry.

Source 2: Testing for glucose concentration in urine samples

Glucose is found in urine samples from patients with diabetes. A convenient way to detect the presence of glucose in urine is to use a glucose paper test strip.



A glucose test strip contains *glucose oxidase*. This enzyme catalyses the conversion of oxygen into hydrogen peroxide. The hydrogen peroxide produced reacts with the substrate on the test strip to form a coloured substance. The simplified reactions are as follows:

$$\text{glucose} + \text{oxygen} \xrightarrow{\text{glucose oxidase}} \text{intermediate X} + \text{hydrogen peroxide}$$

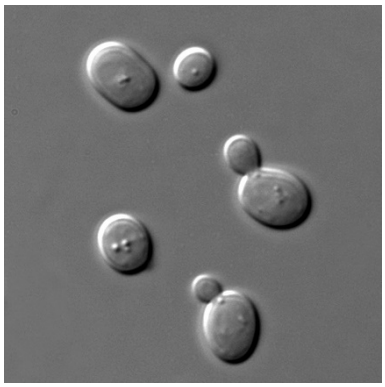
$$\text{substrate} + \text{hydrogen peroxide} \longrightarrow \text{water} + \text{coloured substance}$$

After dipping in the urine sample, the paper test strips change colour if glucose is present. The resulting colour indicates the concentration of glucose semi-quantitatively.

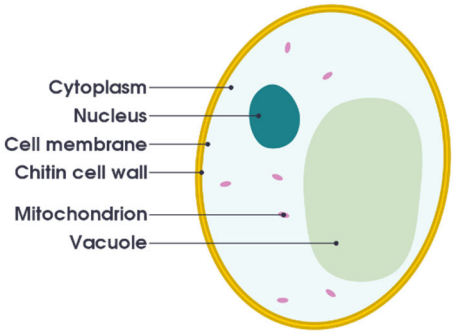
Scan the QR code to learn how to use a glucose test strip.

Source 3: What are yeast and yeast beads?

Yeast (*Saccharomyces cerevisiae*) is a eukaryotic organism. A eukaryotic cell has a true nucleus and membrane-bound organelle. Although yeast cells have cell walls, the chemical composition of their cell walls is different from that of plant cells. The following diagrams show yeast cells under a light microscope and a drawing of a yeast cell, respectively.



Yeast cells under a microscope

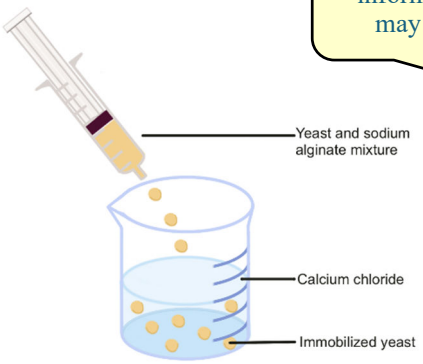


Drawing of a yeast cell

Yeast cells contain invertase, which catalyses the conversion of sucrose to fructose and glucose.

Scientists use yeast for many industrial applications, including brewing beer and making bread. In some applications, scientists immobilise whole yeast cells to form yeast beads using sodium alginate and calcium chloride.

The reading materials provide information about yeast beads, which may be unfamiliar to the students.



Yeast in alginate solution + Calcium chloride ⟶ Yeast beads

(Yeast immobilised in insoluble calcium alginate)

Immobilised yeasts are also active. The yeast beads can be collected and reused after the reaction.

Scan the QR code to learn how to make yeast beads.

學生工作紙（一）

任務 1

- 閱讀以下資訊和資料檔案中的資料。
- 回答隨後的問題。

情境

轉化酶 (Invertase) 是一種可以催化蔗糖分解為果糖和葡萄糖的酶。它在食品工業中被廣泛用於生產奶油、果醬和人工蜂蜜。

酵母(*Saccharomyces cerevisiae*)是一種豐富的轉化酶來源。酵母細胞被固定化以形成酵母凝膠珠，可輕易地從蔗糖溶液中取出並重複使用。

在這次探究，你將研究酵母凝膠珠轉化酶。閱讀資料檔中的資訊，了解這次探究的背景。你將利用你對酶的生物知識以及透過設計有效且可靠的實驗來完成這次探究。

問題

你發現在製造反轉糖漿的過程中，通過改變 pH 值可以控制製造反轉糖漿的時間。因此，你想研究 pH 值對酵母凝膠珠轉化酶活性的影響。

- 你收到以下材料和儀器:

20%的蔗糖溶液	水浴
酵母凝膠珠	葡萄糖試紙
計時器	小瓶
量筒	點滴板
白色瓷磚	勺子
溫度計	塑料滴管
鑷子	顏色圖

你也可以運用實驗室常用的物料及儀器。

掃描此二維碼以查看實驗材料

(a) 簡要描述你將如何使用上述材料來設計探究，以達到上述目標。

- 你可以畫出你的實驗設計。
- 請寫下有關實驗的重要設計決定。
- 你可參考實驗策劃模板(掃描二維碼)。

掃描二維碼以獲取實驗策劃模板

掃描二維碼以獲取 *Google Form* 的副本

資料檔案

你的生物老師要求你閱讀下面的資料，為設計一個與酵母凝膠珠轉化酶有關的科學探究做準備。

資料 1: 轉化酶的工業應用

轉化酶 (Invertase) 是一種可以催化蔗糖分解為果糖和葡萄糖的酶。

$$\text{蔗糖} \xrightarrow{\text{轉化酶}} \text{果糖} + \text{葡萄糖}$$

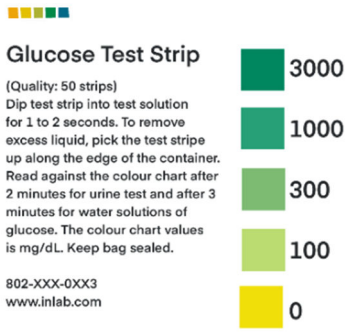
轉化酶在食品工業中被廣泛用於從蔗糖溶液生產 “反轉糖漿”。反轉糖漿含有經轉化酶處理後蔗糖所產生的果糖和葡萄糖混合物。酶反應形成的產物(即果糖和葡萄糖)比起起始物(蔗糖)具有更高的溶解度。

轉化酶在生產軟心巧克力(如瑞士蓮牛奶朱古力夾心)中也有著名的用途。製作這類朱古力的一種方法是在堅硬的糖餡料(即蔗糖)中添加少量轉化酶。經轉化酶處理的蔗糖不再成為固體，而是成為朱古力外殼內的液體餡料。

掃描二維碼，可了解更多關於轉化酶在食品工業中的應用。

資料 2: 尿液中葡萄糖濃度的測試

糖尿病患者的尿液中存在葡萄糖。使用葡萄糖試紙是一種檢測尿液中葡萄糖的便捷方法。



葡萄糖試紙含有葡萄糖氧化酶。這種酶可以催化氧氣轉化為過氧化氫。產生的過氧化氫與試紙上的底物發生反應，形成一種著色物質。這一過程可以概括如下:

$$\text{葡萄糖} + \text{氧} \xrightarrow{\text{葡萄糖氧化酶}} \text{中間體 X} + \text{過氧化氫}$$

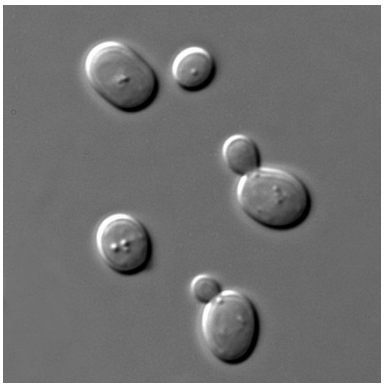
$$\text{底物} + \text{過氧化氫} \longrightarrow \text{水} + \text{著色物質}$$

將試紙浸入尿液後，如果尿液中含有葡萄糖，試紙會發生顏色變化。最終的顏色可以半定量地反映葡萄糖的濃度。

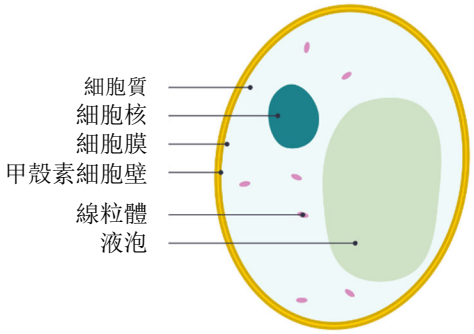
掃描二維碼，了解如何使用葡萄糖試紙。

資料 3: 什麼是酵母和酵母凝膠珠?

酵母(*Saccharomyces cerevisiae*)是一種真核生物。真核細胞具有真正的細胞核和多種具有膜結構的細胞器。雖然酵母細胞有細胞壁，但其細胞壁的化學組成成分與植物細胞的不同。下圖分別為顯微鏡下的酵母細胞圖和酵母細胞繪圖。



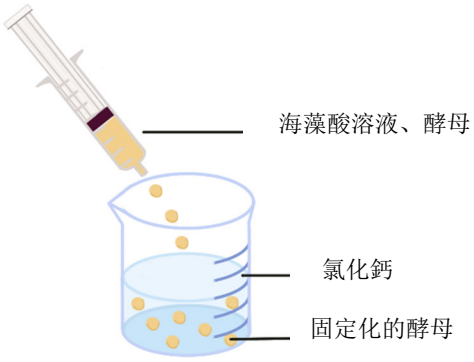
顯微鏡下的酵母細胞圖



酵母細胞繪圖

酵母細胞含轉化酶。轉化酶能催化蔗糖分解為果糖和葡萄糖

科學家利用酵母進行許多工業應用，包括釀造啤酒、製作麵包等。在某些應用中，科學家使用海藻酸鈉和氯化鈣使整個酵母細胞固定，以形成酵母凝膠珠。



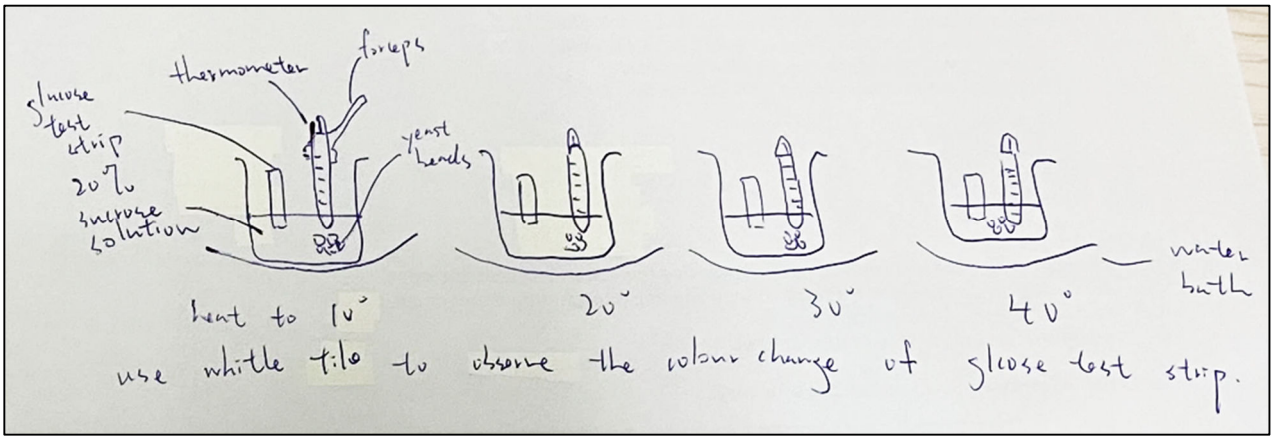
海藻酸溶液中的酵母 + 氯化鈣 ⟶ 酵母凝膠珠

(酵母在非溶性的海藻酸鈣中被固定)

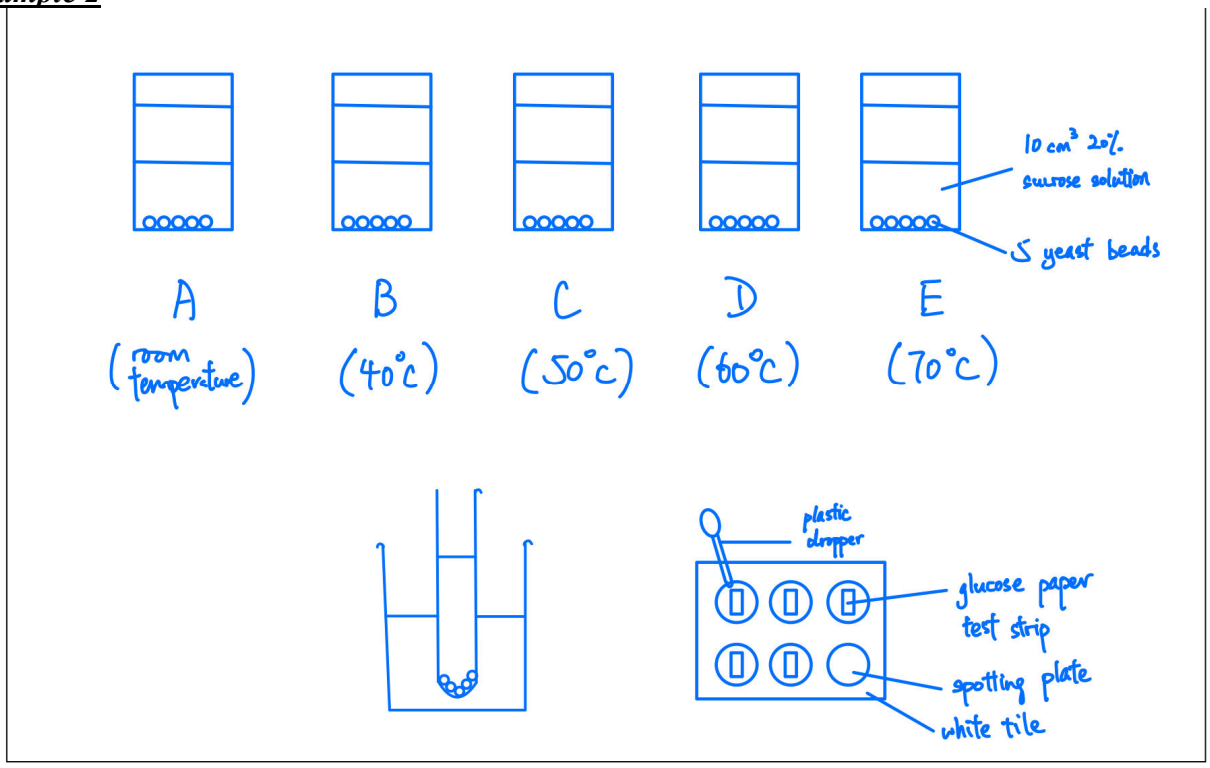
固定化的酵母仍然有活性。酵母凝膠珠在反應後可被回收及重用。

掃描二維碼以查看如何製作酵母凝膠珠。

Sample 1



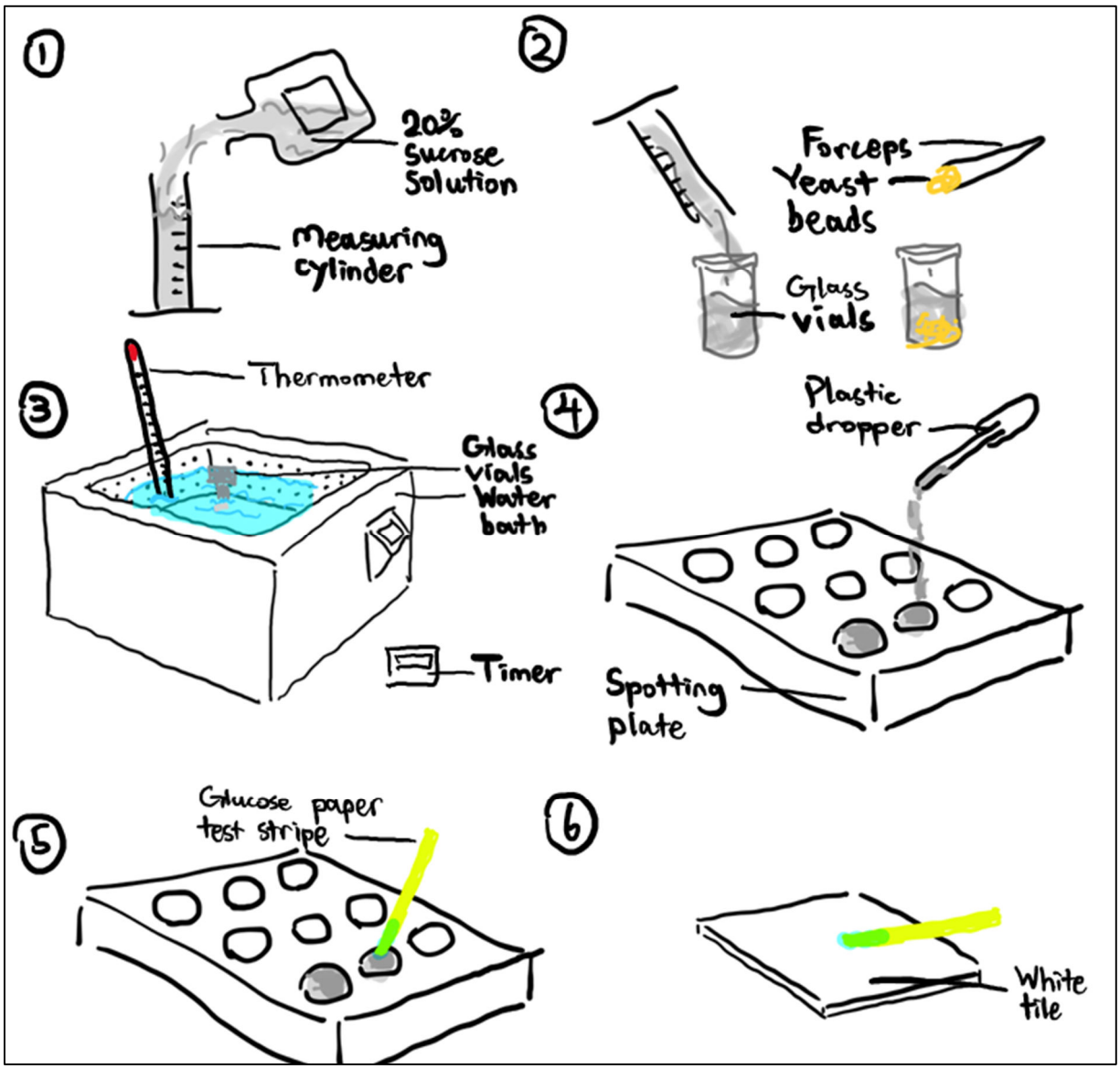
Sample 2

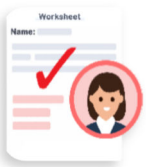


Brief explanation of my design:

Firstly, make some yeast beads by using a plastic dropper. Next, measure 10 cm3 of 20% of sucrose solution by using a measuring cylinder, then transfer the solution into a glass vial and repeat this step for four times. After that, use a water bath and put a thermometer to seek the respective wanted temperatures of the solution, also set a timer for 12 mins. Then, transfer five yeast beads into each glass vial and start the timer once the beads are ur into the vial by a spoon. Afterwards, place a spotting plate on a white tile and add five glucose paper test strips on the plate by a forcep while waiting the experiment to complete. After 12 minutes, use a plastic dropper to add two drops of each of the mixture to the plate. At last, observe the colour change of the test paper to deduce how much sucrose has been converted into glucose.

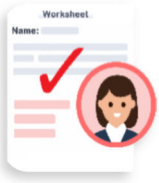
Sample 3





Notes for teachers

- Teachers can select student drawings (anonymised) for discussion.
- Teachers can discuss the following scientific inquiry skills: (1) range and interval of independent variable; (2) measurement of dependent variable; (3) significant assumptions; (4) important precautionary steps; (5) number of yeast beads used.



Notes for teachers

- The following shows the main investigation context that requires students to design an investigation with another independent variable.
- There are some questions that teachers may use to guide students in thinking about or assessing the scientific inquiry skills related to experimental designs.
- Some student work samples are shown below to illustrate possible student thinking.

Task 2

Scenario

Invertase is an enzyme that catalyses the breakdown of sucrose into fructose and glucose. Invertase is often used in the food industry for the production of invert syrup from sucrose.

Yeast (*Saccharomyces cerevisiae*) is a rich source of invertase. Yeast cells are immobilised and form yeast beads that can be easily removed from the sucrose solution and reused.

Since sucrose solutions with different food additives have different pH values, the efficiency of the yeast beads in converting sucrose into fructose and glucose may be different. In this study, you would like to investigate the effect of pH on the invertase activity of the yeast beads.

Design of the investigation

Your teacher has given you the following materials:

5% Sucrose solution at pH 3, 5, 7, 9	Distilled water	Timer
Buffer solution* (pH = 3, 5, 7, 9)	Glucose test strip	Forceps
Yeast bead	Petri dish	Spoon
Plastic vial	Measuring cylinder	White tile
Spotting plate	Plastic dropper	Colour chart

* Buffer solutions are used to maintain the pH of the solution mixture.

Possible questions

1. You have found two different brands of glucose paper test strips in the laboratory. Below you can see the colour charts of the two brands, which you can use to determine the concentration of glucose.

Which brand, A or B, will you use in this investigation? Why?

2. State *one* significant assumption in this investigation.
(An assumption is something we think it is true, though we cannot be sure. A significant assumption is the one that the experiment cannot make any conclusion without assuming it to be true).

3. Your teacher has also given you the following reminders:

Terms are defined using student-friendly language.

Reminders

- *Place the yeast beads in the petri dish containing the buffer solution for at least 5 minutes before mixing with the sucrose solution.*
- *Gently shake the plastic vials with the yeast beads and the sucrose solution from time to time.*

Suppose you have overlooked your teacher's reminders and

(a) forgot to put the yeast beads into the buffer solution before adding them to the sucrose solution.
(b) shook the plastic vials too vigorously and spilled half of the sucrose solution out of the plastic vials.

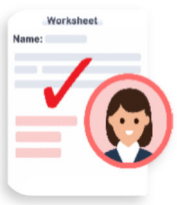
Explain how each of these mistakes would impact the experimental results.

Hints: Be sure to include the following parts in your answers:

- the effect on the data being collected
- explanation for the effect

The checklist serves to scaffold students' responses.

	Impact on experimental results
(a)	
(b)	



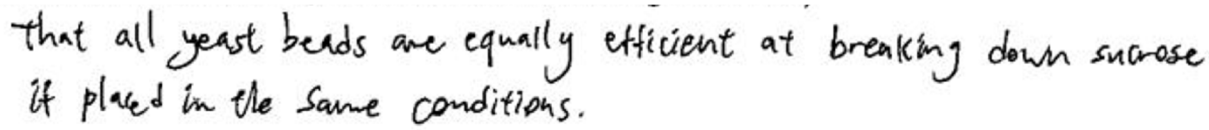
Notes for teachers:

- Q.1 assesses students' ability to reduce measurement errors by choosing the glucose test strip brand that is more sensitive.
- Q.2 assesses students' ability to identify the significant assumption.
- Q.3 assesses students' ability to explain how specific steps can impact on the validity of the data.

The following are some examples of students' responses to Q.2:

Sample 1

Sample 2



About the samples

- Neither sample mentioned the significant assumption concerning the relationship between the measurement and the dependent variable.

The following examples demonstrate varying levels of sophistication in quality:

Unattained

- Environmental conditions are the same.
- Yeast beads have the same size and shape.

Basic

- All yeast beads work the same.

Good

- Amount of invertase in each yeast bead is the same.

Excellent

- Glucose is only contributed by the activity of invertase in the yeast beads.

The following are some examples of students' responses to Q.3(a):

Sample 1

	Impact on experimental results
(1)	The pH value of sucrose solution will be affected, because if yeast beads didn't put into buffer solution, the pH value of yeast beads and sucrose solution will be diffrent. So the result won't be the pH you want.

Sample 2

	Impact on experimental results
(1)	The amount of glucose may be higher initially for the set-ups with lower pH. The buffer solution ensures that the yeast beads are already at the pH of the sucrose solution. In this case, the yeast beads will only change its pH once in contact with the sucrose solution, meaning that it will not be denatured beforehand and more of the enzymes will be able to break down sucrose into glucose.

Sample 3

	Impact on experimental results
(1)	Since ~~it is not~~ at yeast beads were not added into their respective buffer solutions, pH of yeast beads are not the same ~~as~~ with sucrose solutions, that the pH of solution obtained after the expiriment is different from the initial pH of the sucrose solution, resulting in either higher or lower glucose concentration ~~as~~ in the solution obtained.

About the samples

- Sample 1 did not clearly explain how omitting the precautionary step would impact the yeast beads' ability to reach the desired pH at the start of the experiment.
- Both Samples 2 and 3 described the effect of this missing step. Sample 3 specifically stated that the effect could result in either a higher or lower glucose concentration, depending on the pH profile of the invertase enzyme. In contrast, Sample 2 assumed a lower pH would lead to higher invertase activity, despite lacking experimental evidence to support that claim.

任務 2

情境

轉化酶是一種催化蔗糖分解為果糖和葡萄糖的酶。轉化酶通常用於食品工業，將蔗糖中生產轉化糖漿。

酵母(*Saccharomyces cerevisiae*)是轉化酶的一個豐富來源。酵母細胞被固定形成酵母凝膠珠，可以很容易地從蔗糖溶液中移除並重新使用。

由於含有不同食品添加劑的蔗糖溶液具有不同的 pH 值，酵母凝膠珠將蔗糖轉化為果糖和葡萄糖的效率可能不同。在這項研究中，你想研究 pH 值對酵母凝膠珠中的轉化酶活性的影響。

實驗設計

你的老師給了你提供了以下物料。

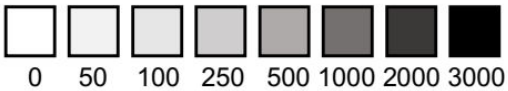
pH 值分別為 3、5、7、9 的 5% 的蔗糖溶液	蒸餾水	計時器
緩衝溶液* (pH = 3， 5， 7， 9)	葡萄糖試紙	鑷子
酵母凝膠珠	培養皿	勺子
塑料小瓶	量筒	白色瓷磚
點滴板	塑料滴管	顏色圖

* 緩衝溶液是用來維持溶液混合物的 pH 值的。

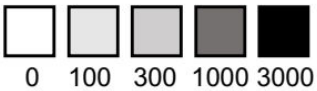
參考問題

1. 你在實驗室找出了兩種不同品牌的葡萄糖試紙。下面你可以看到這兩個品牌的顏色圖，你可以用它來測定葡萄糖的濃度。

品牌 A



品牌 B



在這次實驗中，你將使用哪個品牌，A 或 B？為什麼？

2. 說明這項探究中的*一個*重要假設。(假設是我們認為是真實的東西，儘管我們不能確定。一個重要的假設是，如果不假設它是真的，實驗就不能得出任何結論)。

3. 你的老師也給了你以下提示。

提示
• 在與蔗糖溶液混合之前，將酵母凝膠珠放在含有緩衝溶液的培養皿中至少 5 分鐘。 • 不時輕輕搖動裝有酵母凝膠珠和蔗糖溶液的塑料小瓶。

假設你忽略了老師的提示，並且

(a) 忘了在加入蔗糖溶液前將酵母凝膠珠放入緩衝溶液中。

(b) 過於激烈地搖晃塑料小瓶，從塑料小瓶中溢出一半的蔗糖溶液。

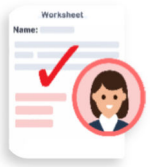
解釋一下這些錯誤會如何影響實驗結果。

提示：請確保在你的答案中包括以下部分。

- 對正在收集的數據的影響
- 對該影響的解釋

	對於實驗結果的影響
(a)	
(b)	

Laboratory Manual



Notes for teachers

- Teachers can distribute the manual for students to read and prepare before the investigation.
- Teachers can ask questions to check if students fully understand the procedures (e.g., how many glucose test strips do you need for this experiment? Why?).
- The *Supplementary Resource* section contains the list of materials.
- Teachers can print the *Data Collection Sheet* and laminate the printouts for use in class.
- Scan the QR code to view the process of the experiment.

Task 3:

- Read the following procedures to carry out the investigation.

Procedure

Preparation of yeast beads

1. Add 10 mL of 10% yeast (in a vial) to 10 mL of 2% sodium alginate solution in a 50 mL-tube.
2. Mix the solution well by inverting the 50 mL-tube to make a yeast–sodium alginate solution.
3. Hold the plastic dropper (without cap) with a stand and clamp.
4. Pour 50 mL 2% $CaCl_2$ (calcium chloride) into a plastic cup/100 mL-beaker.
5. Assemble the set up shown in *Figure 1*.
6. Add the yeast sodium alginate solution to the plastic dropper (a bead should form when the drop comes into contact with the $CaCl_2$ solution and falls to the bottom of the beaker).
7. Wait 5 minutes until the beads have hardened.
8. Discard any floating yeast beads with a plastic spoon.
9. Collect the beads with a sieve.
10. Wash the beads several times with distilled water from a wash bottle over a plastic cup.

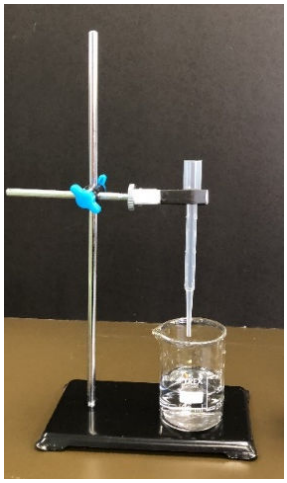


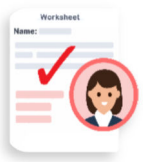
Figure 1

Incubation of the yeast beads in buffer solution

1. Add 5 mL buffer solution (pH = 3.0, 5.0, 7.0, 9.0) to 4 different petri dishes.
2. Use a spoon to gently move at least 15 yeast beads into each buffer solution (pH = 3.0, 5.0, 7.0, 9.0).
3. Wait at least 5 minutes.

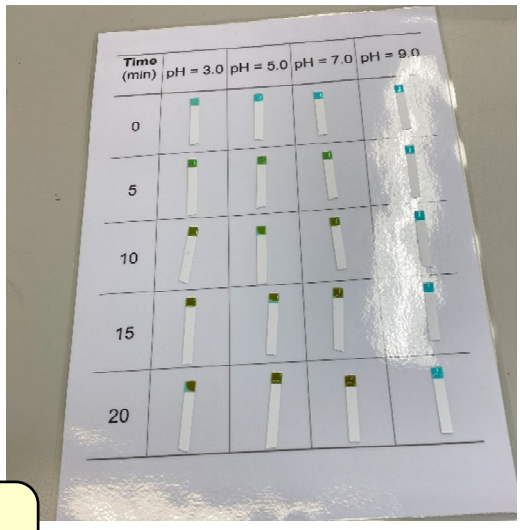
Testing the invertase activity

1. Transfer 5 mL of the sucrose solution with a pH of 3.0 into a plastic vial.
2. Repeat *Step 1* with the sucrose solution with different pH values (5.0, 7.0 and 9.0).
3. Transfer 15 yeast beads into each plastic vial using a spoon and a pair of forceps.
4. At time = 0 minute, remove a small drop of sample from each vial with a plastic dropper and place it on the laminated spotting plate sheet.
5. Close the plastic vial and swirl it gently from time to time.
6. Repeat *Step 4* at time points 5, 10, 15 and 20 minutes.
7. When you have collected all the samples, dip the glucose paper test strip into each sample.
8. Observe and record the colour change, if any, after 1 minute.
9. Determine the glucose concentration from the colour chart.



Notes for teachers

- Remind the technician to adjust the relative concentration of sucrose solution as different brands of glucose test strips have different sensitivity.
- Laminated data collection sheets are commonly used in microscale activities.
- Scan the QR code for copy of the *Data Collection Sheet*.



The *Data Collection Sheet* provides guidance for students to collect data.

實驗指南

任務 3:

- 閱讀以下實驗步驟以進行探究:

實驗步驟

酵母凝膠珠的製備

1. 將 10 mL 10%的酵母(在小瓶中)加入到盛有 10 mL 升 2%的海藻酸鈉溶液的 50 mL 試管中。
2. 倒置 50 mL 試管將溶液充分混合，使之成為酵母–海藻酸鈉溶液。
3. 用支架和夾子夾住塑料滴管(無蓋)。
4. 將 50 mL 2%的 $CaCl_2$ (氯化鈣)倒入一個塑料杯中/100 mL 燒杯 。
5. 組裝*圖 1* 中所示的裝置。
6. 在塑料滴管中加入海藻酸鈉酵母溶液(當滴管接觸到 $CaCl_2$ 溶液並落到燒杯底部時應形成一個珠子)。
7. 等待 5 分鐘，直到珠子變硬。
8. 用塑料勺子丟棄任何漂浮的酵母凝膠珠。
9. 用篩子收集珠子。
10. 用洗瓶中的蒸餾水沖洗幾次塑料杯上的酵母凝膠珠。

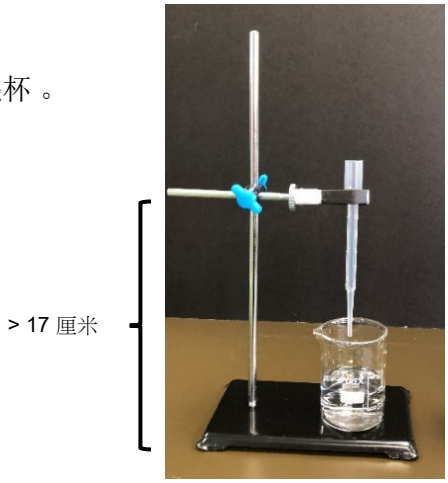


圖 1

酵母凝膠珠在緩衝溶液中的培育

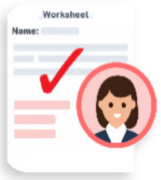
1. 在 4 個不同的培養皿中加入 5 mL 的緩衝溶液(pH=3.0，5.0，7.0，9.0)。
2. 用勺子將至少 15 個酵母凝膠珠輕輕移入每個緩衝溶液(pH=3.0，5.0，7.0，9.0)。
3. 等待至少 5 分鐘。

測試轉化酶的活性

1. 將 5 mL pH 值為 3.0 的蔗糖溶液轉移到一個塑料小瓶中。
2. 用不同 pH 值的蔗糖溶液(5.0、7.0 和 9.0)重複步驟 1。
3. 用一個勺子和一把鑷子將 15 個酵母凝膠珠轉移到每個塑料瓶中。
4. 在時間為 0 分鐘時，用塑料滴管從每個小瓶中取出一小滴樣品，並將其放置在薄板狀的點滴板上。
5. 關上塑料小瓶，並不時地輕輕旋轉。
6. 在 5、10、15 和 20 分鐘的時間點重複步驟 4。
7. 當你收集完所有的樣品後，將葡萄糖紙測試條浸入每個樣品。
8. 觀察並記錄 1 分鐘後的顏色變化(如果有的話)。
9. 根據顏色圖確定葡萄糖的濃度。

掃描二維碼以獲取數據收集表的副本

Teacher Notes 2



Notes for teachers

- The following are some possible questions that teachers can use to guide students in thinking about or assessing their scientific inquiry skills related to data analysis and interpretation.
- Some student work samples are shown below to illustrate possible student thinking.

Task 4

1. Based on the data collected, describe and explain the effect of pH on yeast bead invertase activity.

2. Tom performed the same experiment. He found that all the glucose test strips of the samples at pH 7 and 9 at 0, 5, 10, and 20 minutes gave a negative result.

   You found that your group's results are similar to the general trend observed in the class data. You suspected that Tom's results are anomalous data and had some errors.

   (a) By comparing your results with those of Tom, identify the possible errors in Tom's results.

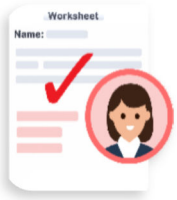
   (b) How would you further confirm that the results by Tom are anomalous?

   (c) Explain the possible causes for the errors.

3. Tom would like to determine the optimum pH of yeast bead invertase accurately.

   (a) Based on the data, explain the limitations of the experimental design in finding the optimum pH of yeast bead invertase.

   (b) Describe how you would modify this experiment to obtain a more accurate estimate of the optimum pH of yeast bead invertase.

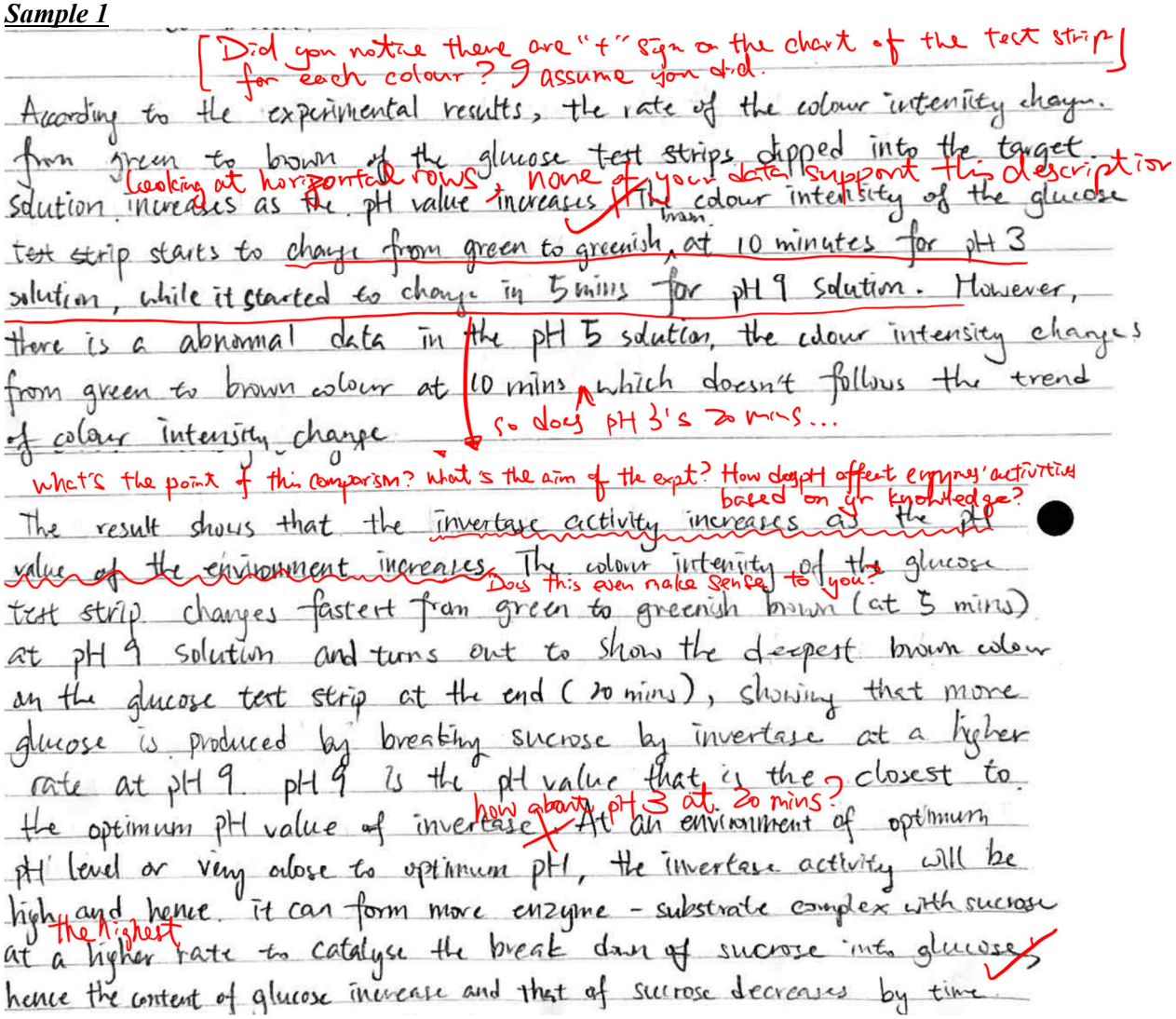


Notes for teachers

- Q.1 assesses students' ability to describe and explain data in simple data sets.
- Q.2 assesses students' ability to identify data inconsistent with the general trend or patterns observed within the class data and suggest ways to confirm if the data are anomalous as well as explanations for the occurrence.
- Q.3 assesses students' ability to assess the adequacy of the selection of the range and interval of the independent variable in determining the optimum pH of the yeast bead invertase, and suggest possible modifications to improve the accuracy of the designs to achieve this aim.

The following are some examples of student responses to Q.1:

Sample 1


[Did you notice there are "+" sign on the chart of the test strip for each colour? I assume you did.]
According to the experimental results, the rate of the colour intensity chaym. from green to brown of the glucose test strips dipped into the target solution increases as the pH value increases. The colour intensity of the glucose test strip starts to change from green to greenish, at 10 minutes for pH 3 solution, while it started to change in 5 mins for pH 9 solution. However, there is a abnormal data in the pH 5 solution, the colour intensity changes from green to brown colour at 10 mins which doesn't follows the trend of colour intensity change
looking at horizontal rows, none of your data support this description
so does pH 3's 20 mins...
what's the point of this comparism? what's the aim of the expt? How does pH affect enzyme activities based on yr knowledge?
The result shows that the invertase activity increases as the pH value of the environment increases. The colour intensity of the glucose test strip changes fastert from green to greenish brown (at 5 mins) at pH 9 solution and turns out to show the deepest brown colour on the glucose test strip at the end (20 mins), showing that more glucose is produced by breaking sucrose by invertase at a higher rate at pH 9. pH 9 is the pH value that is the closest to the optimum pH value of invertase. At an environment of optimum pH level or very close to optimum pH, the invertase activity will be high and hence it can form more enzyme - substrate complex with sucrose at a higher rate to catalyse the break down of sucrose into glucose, hence the content of glucose increase and that of sucrose decreases by time.
Does this even make sense to you?
how about pH 3 at 20 mins?
the highest

Sample 2

As the pH of sucrose solution increased from 3 to 5, the color intensity of glucose test strip remained the same for the first 15 minutes. However, at the 20th minute, the color intensity of glucose test strip of pH 5 was higher than that of pH 3.

As the pH of sucrose solution increased from 5 to 9, most of the color intensity of glucose test strip at their respective time frame decreased, while only some remained unchanged.

??

As time went on, the color intensity of glucose test strips increased. not for pH 9.

As the optimum pH of invertase is at pH 4.5, when pH of sucrose solution increased from 3 to 5, the pH was closer to the optimum pH. Hence as pH of sucrose solution increased from pH 3 to 5, a smaller proportion of invertase would be denatured, so the chance of formation of enzyme-substrate complex increases, more sucrose can be broken down to fructose and glucose, hence the invertase activity increases.

However, as pH of sucrose solution increased from 5 to 9, the pH became further away from the optimum pH. Hence as pH of sucrose solution increased from pH 5 to 9, a larger proportion of invertase would be denatured, so the chance of formation of enzyme-substrate complex decreases, less sucrose can be broken down to fructose and glucose, hence the invertase activity decreases.

Sample 3

Among all pH, pH7 took the shortest time to produce the largest amount of glucose. Also, after calculating the invertase activity by glucose amount/time, it is shown that the invertase activity increased from pH3 to pH7, but decreased from pH7 to pH9, the invertase activity was the highest in pH7. This indicates that pH7 is the optimum pH.

At optimum pH, which is pH7, invertase activity is at its maximum. While at unsuitable pH, invertase activity decreases because unsuitable pH causes denaturation of enzymes. Substrates can no longer fit into the active site of enzymes to form enzyme-substrate complexes as the shape of active sites are changed, this causes invertase to slowly lose its catalytic ability permenantly and results in above results.

About the samples

- Sample 1 did not describe the trends and patterns observed in the data obtained and did not provide explanation for the trends and patterns observed.
- Sample 2 described the trends and patterns observed in the data obtained, but the description lacked clarity. In the explanation, it was wrongly stated that the optimum pH was 4.5, and the explanation did not explain why extreme pH would denature the enzyme.
- Sample 3 described the pH profile of the yeast bead invertase by relating it to the data obtained. It also explained the effect of extreme pH on the enzyme activity.

教師筆記（二）

任務 4

參考問題

1. 根據獲得的數據,描述並解釋 pH 值對酵母凝膠珠中的轉化酶活性的影響。

2. 小明進行了相同的實驗。他發現在 pH 7 和 9 的樣本在 0、5、10 和 20 分鐘時,所有的葡萄糖試紙檢測結果均為陰性。

   你發現你所屬小組的實驗結果與全班整體數據趨勢相似。你懷疑小明的結果為異常數據並可能存在錯誤。

   (a) 通過將你的結果與小明的結果進行比較,識別小明結果可能存在的錯誤。

   (b) 你會如何進一步確認小明的結果是異常的?

   (c) 解釋可能導致這些錯誤的原因。

3. 小明希望準確地確定酵母凝膠珠中的轉化酶活性的最佳 pH 值。

   (a) 根據數據,解釋在確定酵母凝膠珠中的轉化酶最佳 pH 值時,現有實驗設計存在的局限性。

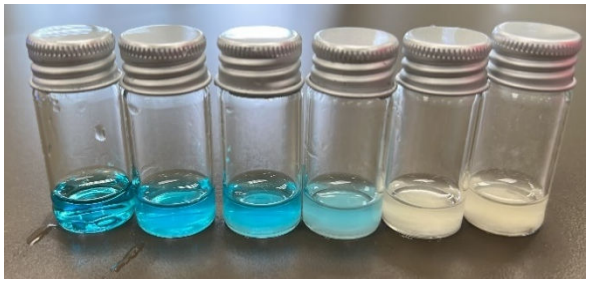
   (b) 描述你將如何修改這個實驗,以更準確估計酵母凝膠珠中的轉化酶活性的最佳 pH 值。

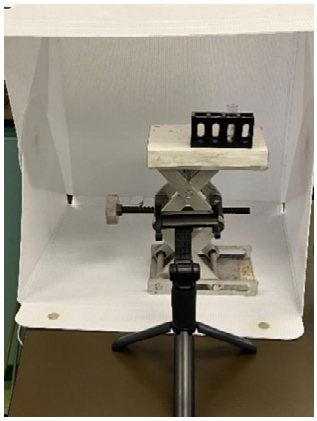
Supplementary Resources

Possible Modifications

1. Investigating the rate of yeast bead invertase quantitatively

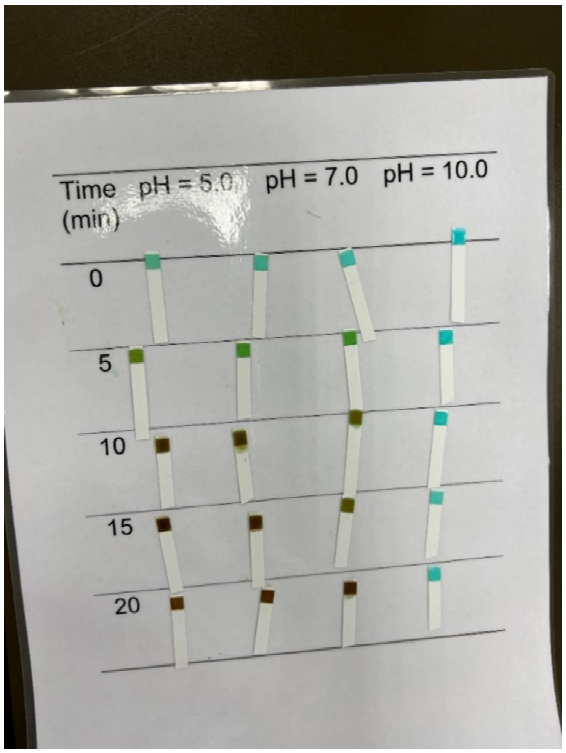
- The reducing sugars produced by the invertase can be quantified using quantitative Benedict's test.
- A colorimeter can be used to determine the amount of reducing sugar produced.
- Details can be found in Hale (2023).

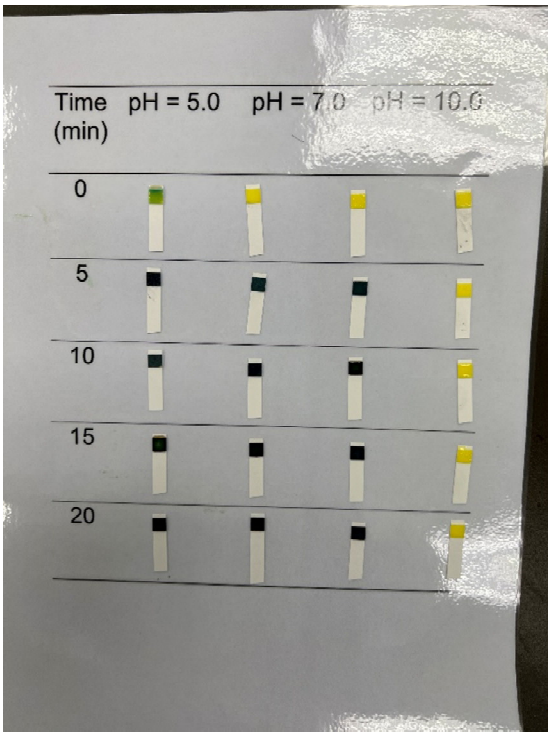




2. Comparing the sensitivity of two brands of glucose test strips

- The sensitivity of different brands of glucose test strips can be compared.





Technician Notes

Materials for Task 3

Chemicals to be prepared

- 10% yeast extract (1 mL in 1.5 mL tube) (to be prepared on that day) (Add 15 g yeast in 150 mL distilled water. Add a spoonful of sugar. Stir on a magnetic stirrer. Wait for 30 minutes to activate the yeast. Keep stirring. Aliquot just before the experiment.)
- 2% sodium alginate (food grade). Add 200 mL of distilled or deionised water and a stir bar. Heat the solution. Slowly add some sodium alginate to dissolve it. Add more powder slowly (5 g in total). Make up volume to 250 mL. Store the solution at 4°C.

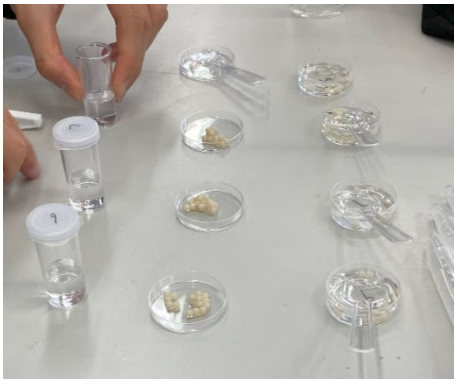
Scan the QR code to watch a video on how to prepare 2% sodium alginate.

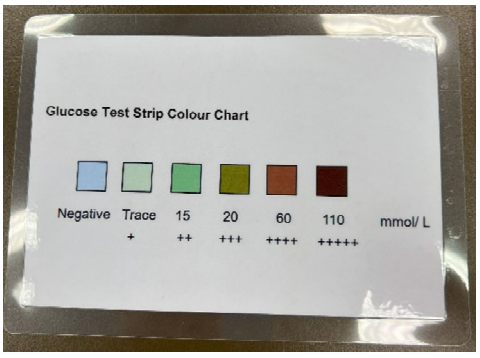
Materials for each group

• 10 mL 2% Sodium alginate in 50 mL tube	• Plastic forceps X 4	• Glucose test strips X 20
• 10 mL 10% Yeast in a plastic vial	• 3 mL Plastic disposable pipette (with part of the head cut)	• Rubbish bin
• 100 mL Beaker X2	• Mini petri dish X 12	• 50 mL 2% calcium chloride
• Spoon (for removing floating yeast bead)	• Stand and clamp	• Timer
• Sieve	• Wash bottle (with distilled water)	

Notes:

- Use 5% to 20% sucrose solution depending on the brand of glucose test strips.
- Do *not* use sodium phosphate buffer as alginate beads can react with the buffer.
- The time for *Step 8* (i.e., testing the invertase activity) depends on the brand of glucose test strips.





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Bryer, P. J. (2016). Exploring catalase and invertase activity using sodium alginate–encapsulated yeast (yeast spheres). *Journal of Microbiology & Biology Education*, *17*(3), 490–491.

Hale, J. (2023) Using immobilised yeast synoptically at A-level. *School Science Review*, *104*(387), 13–17.

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