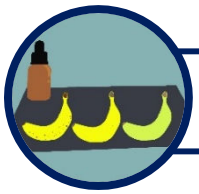
Banana Ripening Investigation



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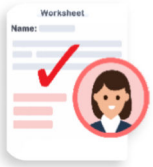
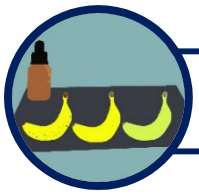


Notes for teachers

- 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



Banana Ripening Investigation

Overview

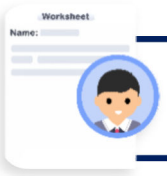
- The *Banana Ripening Investigation* is about why bananas become sweet during ripening.
- The investigation involves hypothesis testing, in which students propose an explanatory hypothesis.
- Students design food tests to investigate the biochemical changes that occur during the ripening process.
- Students are given the opportunity to design and carry out experiments in which they make predictions from the hypothesis, determine appropriate ranges and intervals for data collection, and consider the generalisability of their data.

Teaching Plan & Key Features

Lesson	Lesson sequence	Duration (mins)	Resources
Stage ❶ Preparing for the investigation • Students observe what happened to the overripe banana to raise their curiosity of the biochemical changes during the ripening process.			
1	• The teacher performs a demonstration to show the fluorescent blue ring around the black spot on an overripe banana. • The teacher invites students to propose possible biochemical changes that may occur during the fruit ripening process in *Worksheet 1*.	40	*Worksheet 1*
Stage ❷ Designing the investigation			
2	• The teacher distributes *Worksheet 2* and introduces the investigation context. • The teacher discusses with students questions related to the experimental design. • The teacher provides students with the laboratory manual for preparation at home.	40	*Worksheet 2,* Teacher Notes 1
Stage ❸ Carrying out the investigation • Students use microscale instrumentation that reduces the time of the experiments (**Microscale Instrumentation**).			
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 share their data on *Padlet* (*Data-sharing Web Platform*). • Students evaluate their data to determine if the hypothesis is supported or refuted and consider how to gather additional evidence.			
Before Lesson 4	• Students complete data reporting and analysis at home. • Teacher collects and marks student responses.		Teacher Notes 2
4	• Teacher provides feedback on students' performance related to data reporting and analysis**.**	40	Teacher Notes 2

Important Notes

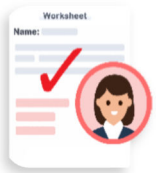
- This investigation is considered relatively simple. It is more suitable for use in Secondary 3 or Secondary 4.



Instructional Materials

Stage 1 Preparing for the investigation

Student Worksheet 1



Notes for teachers

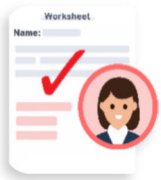
- Teachers perform a demonstration to show the fluorescent blue rings around the black spots on overripe banana.
- Teachers can ask students to propose changes that might have occurred during banana ripening that led to their observations and other possible changes.
- Scan the QR code to see a video clip.

The demonstration arouses students' curiosity about the process of fruit ripening.

Task 1

Watch the demonstration and answer the following questions:

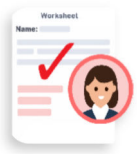
1. What do you observe in the overripe banana?
2. What do you think might have happened during the banana ripening process?
3. Based on your daily-life experience, what other changes might have occurred during the ripening of banana?



Notes for teachers

- Ripening is a catabolic process that involves a lot of biochemical process and physiological changes.
- Black spots are visible on the skin of a banana as it becomes overripe. Under ultraviolet light in darkness, a fluorescent blue ring can be observed around each black spot. This is formed from the breakdown of chlorophyll during the ripening process.
- This can be used as the basis for investigative practical work activities, where students are challenged to hypothesize about what they observe and the reasons for their observations.
- The website https://www.saps.org.uk/teaching-resources/resources/1306/why-do-bananas-fluoresce-an-unexpected-view-of-chlorophyll/ provides an excellent resource related to this topic.

Student Worksheet 2



Notes to teachers

- Teachers can distribute *Worksheet 2* and instruct students to design their experimental set-ups.
- Teachers can show students the materials and apparatuses to facilitate their design.

Task 2

- Read the following information and answer the questions that follow.

Scenario

Godfrey bought some bananas. He ate a green one and complained that it tasted flat. His biology teacher told him that green bananas are not yet ripe and suggested to Godfrey that he should store the bananas and eat them until the bananas turn yellow. Godfrey ate the bananas that were stored for different days and noticed that the bananas that were stored longer tasted sweeter.

Godfrey wondered *why* bananas become sweeter when they ripen further. He hypothesized that biochemical changes occur during the ripening process (*Figure 1*).

To test this hypothesis, he investigated how the starch and sugar contents of bananas changed with the degree of their ripeness.

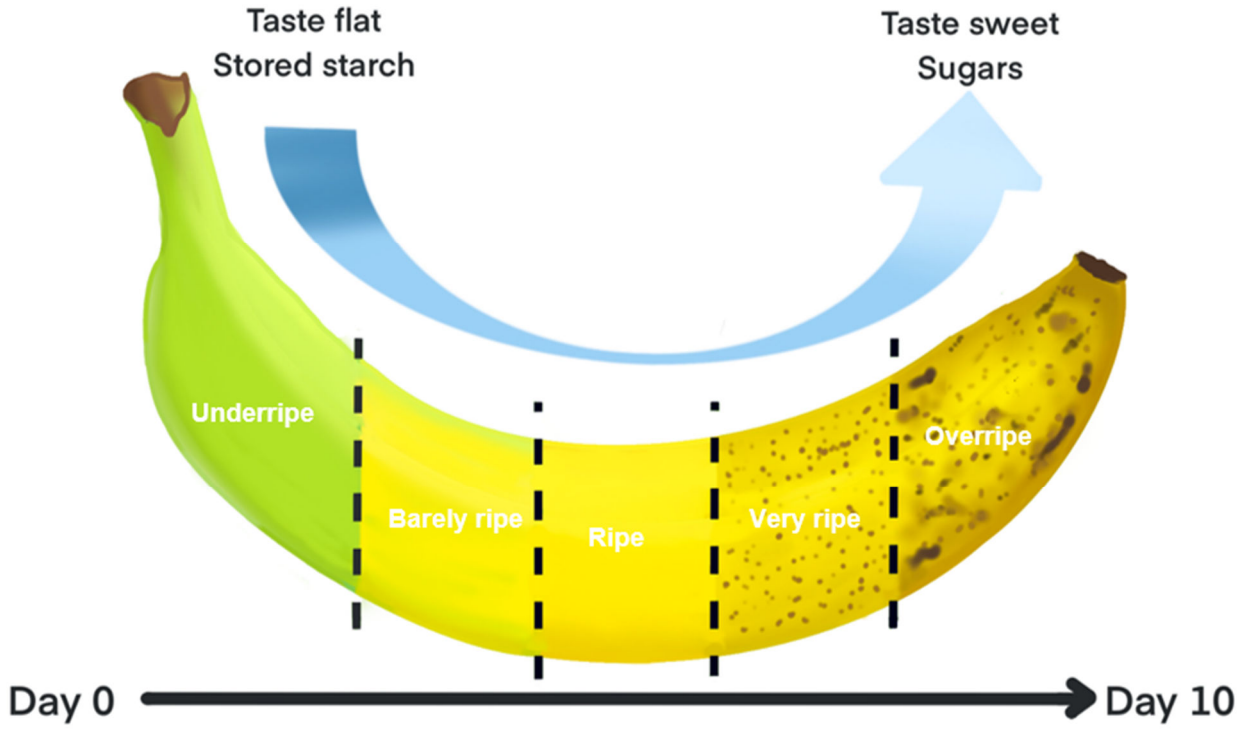
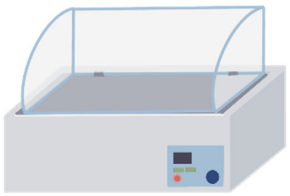
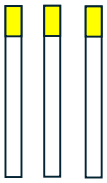
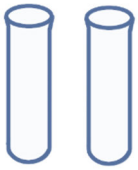
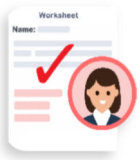


Figure 1. Godfrey's hypothesis about the biochemical process that make ripe bananas sweeter than unripe bananas

Design an investigation to test Godfrey's hypothesis using the following materials:

Unripe bananas 	Muslin cloth	Mortar and pestle 
Benedict's solution 	Filter funnel	Water bath 
DCPIP solution 	Protein test paper 	Iodine solution 
Measuring cylinder 	Beaker 	Test tubes 
Refrigerator 	Wash bottle with distilled water 	Electronic balance 
Knife 	White tile	

The diagrams provide visual scaffolds to help students understand the materials and apparatuses for the investigation. Students need to choose the relevant materials for the investigation.



Notes for teachers

- The following are some questions that teachers may use to guide students in thinking about or assessing scientific inquiry skills related to their experimental designs.
- Student work samples are shown below to illustrate possible student thinking to some questions.

Possible questions

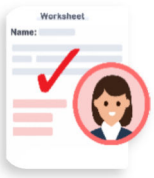
1. (a) Propose a hypothesis to explain *why* bananas become sweeter when they ripen.
   (b) If Godfrey's hypothesis is correct, what are the predicted results of the experiment?

2. Below are two suggestions from Godfrey's classmates:

   Mary: Use the same banana, cutting a slice of banana on different storage days for testing.
   Tom: Use different bananas stored for different days for testing.

   Discuss the strengths and limitations of each design.

	Strength	Limitation
Mary's design		
Tom's design		

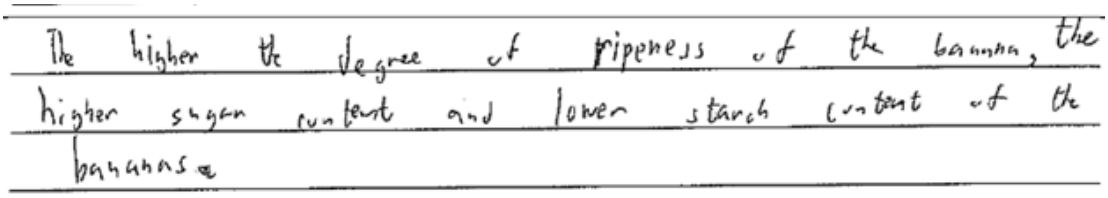


Notes to teachers

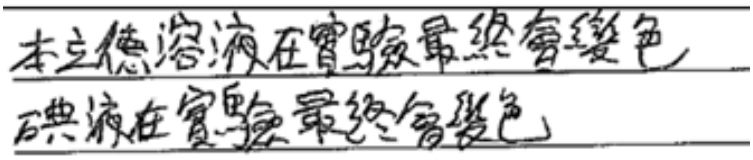
- Q.1(a) and (b) assess students' ability to propose a hypothesis and make predictions based on their hypothesis.
- Q.2 assesses students' ability to identify the strengths and limitations of alternative designs (i.e. within and between subject designs).

The following are some examples of students' responses to Q.1(b):

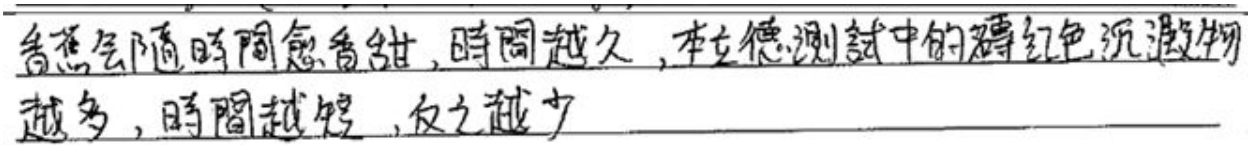
Sample 1



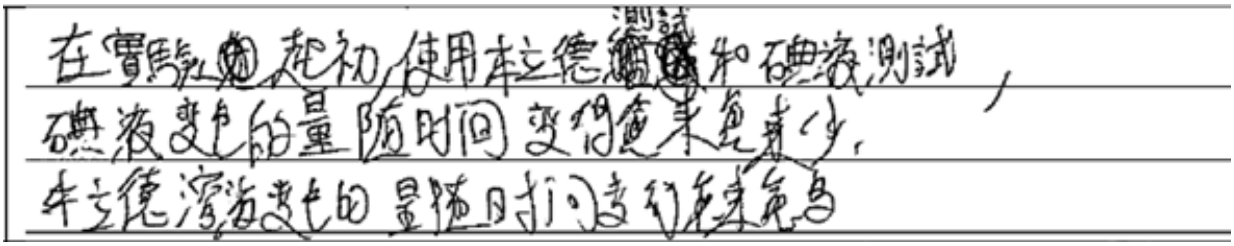
Sample 2



Sample 3



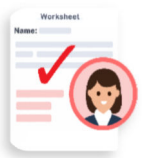
Sample 4



About the samples

- Sample 1 did not describe the results of the chemical tests. Instead, it describes the inference from the results of the tests.
- Sample 2 described the predicted results without relating them to which samples.
- Sample 3 correctly described the predictions of the results of the Benedict's test but did not mention the predictions about the iodine test.
- Sample 4 mentioned both tests, but the predicted results were unclear.

Laboratory Manual



Notes for teachers

- Teachers can distribute the manual for students to read and prepare before the investigation.
- Teachers can provide students with videos demonstrating how to perform the food tests before they carry out the experiment. These instructional videos can be easily sourced from textbook publishers' audio-visual resources.
- Teachers can ask questions to check if students fully understand the procedures.
- The *Supplementary Resource* section contains the list of materials.
- Scan the QR code to view the process of the experiment.

Task 4

- Read the following procedures to carry out the investigation.

Procedure

Preparation of the banana samples

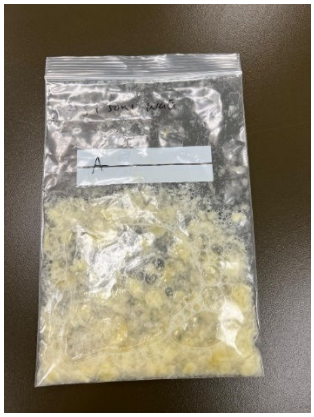
1. Label the bananas with a storage duration of 0, 2, and 4 days as samples *A*, *B*, and *C*, respectively.
2. Weigh 10 g of banana sample *A* using an electronic balance.
3. Put the sample into a plastic bag.
4. Add 20 mL of distilled water, and seal the plastic bag.
5. Mash the banana in a plastic bag to a pulp.
6. Filter the mashed materials through a double layer of moist muslin cloth over a filter funnel and collect the filtrate (i.e., the extract) in a 100-mL beaker.
7. Repeat *Step 2* and *Step 3* with the other two banana samples.

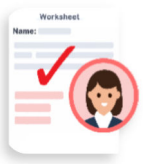
Test for reducing sugar: Benedict's test

8. Add 1 cm^3 of filtrates of each banana sample into three test tubes.
9. Add 2 cm^3 of Benedict's solution to each tube. Shake the contents gently to mix well.
10. Place the test tubes in the mini water bath.
11. Wait for 5 minutes, and shake the test tubes at intervals.
12. Observe and compare any colour changes in the solution and the amount of precipitate formed.

Test for starch: Iodine test

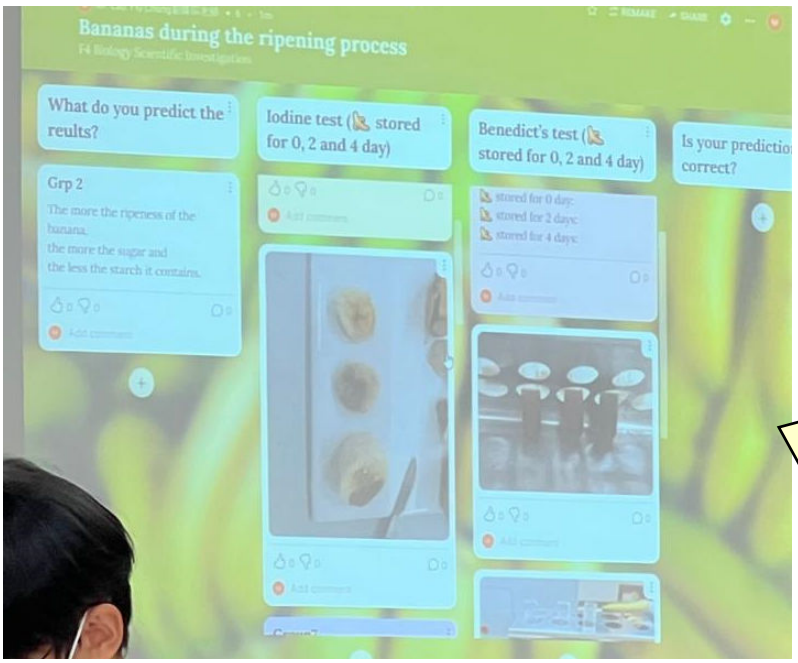
13. Cut a slice of banana from each banana sample on a white tile.
14. Add 10 drops of iodine solution to the samples with the dropper bottle.
15. Observe and compare the intensity of the blue-black colour.





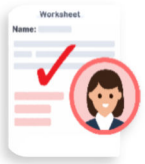
Notes for teachers

- A plastic bag can be used for mashing the banana, which saves time compared to grinding the banana using a mortar and pestle.
- Test tubes can be replaced with glass vials or microcentrifuge tubes.
- Teachers may ask students to take photographs of their experimental results. These photographs can then be used by students to check if their results match their initial predictions, and can also be shared with their classmates.



Padlet is a real-time collaborative web platform that allows students to share photographs, text, and other content with their peers.

Teacher Notes 2



Notes for teachers

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

Task 5

Possible questions

1. Based on the data obtained, evaluate whether the proposed hypothesis is supported.

2. Ada found that reducing sugars could not be detected in all the banana samples. She believed that this was because the ripening process was too slow and that 4 days were not enough for the ripening process. How would you change the experimental design to verify if her thought was right?
   Tick '✓' the correct box below and explain your choice.

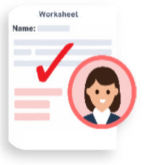
   Modification:

   ☐ Repeating the experiment with bananas stored for 0, 1, 2, 3, and 4 days.
   ☐ Repeating the experiment with bananas stored for 0, 4, and 8 days

   My explanation:

3. Your classmate found that the banana samples that ripened after 2 days and the samples that ripened after 4 days had similar colour intensity and gave a similar amount of precipitate in the Benedict's test, based on visual inspection.

   What would you suggest him to do to more accurately determine if there is a difference in the amount of reducing sugars in the two samples? Explain your answer.



Notes for teachers

- Q.1 assesses students' ability to evaluate whether the hypothesis is supported, refuted or remains undetermined according to the data.
- Q.2 assesses students' ability to suggest further data collection to address the limitations of the experimental design.
- Q.3 assesses students' ability to suggest valid improvements to reduce the measurement errors.

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

Sample 1

5.(a) 艾達進行實驗後發現，所有的香蕉樣本都沒有檢測到還原糖。她認為香蕉的成熟過程太慢，四天的時間對香蕉的成熟過程並不足夠。你會如何改動實驗設計以驗證她的看法是否正確？在適當的方格內加 "✓" 以顯示你的選擇。解釋你的選擇。

改動：

☑ 以存放了 0 天、1 天、2 天、3 天和 4 天的香蕉重覆進行實驗

☐ 以存放了 0 天、4 天和 8 天的香蕉重覆進行實驗

我的解釋：

將不同存放時間的香蕉進行本立德測試，能有效檢測到磚紅顏色的改變，如果第四天的香蕉是磚紅色沉澱物，才證明出香蕉成熟過程過慢並和前三天的本立德試驗結果對比，並且這個改動可以更精確觀測到變化，準確得知成熟時間

Sample 2

改動：

☐ 以存放了 0 天、1 天、2 天、3 天和 4 天的香蕉重覆進行實驗

☑ 以存放了 0 天、4 天和 8 天的香蕉重覆進行實驗

我的解釋：

因為艾達應為存放4天對存放香蕉的成熟過程不足，所以可以用存放8天的香蕉和4天的再次重覆實驗作比較。

Sample 3

改動：

☐ 以存放了 0 天、1 天、2 天、3 天和 4 天的香蕉重覆進行實驗

☑ ·以存放了 0 天、4 天和 8 天的香蕉重覆進行實驗

我的解釋：

用存放8天的香蕉更能和存放4天的香蕉有鮮明的對比，结果量度減少誤差，提升结果精確性。而只相隔一天的存放時間會令結果十分相似（及0天），大大增加量度结果時的誤差。

同時艾達想証明存放4天的香蕉成熟度不足，第一次實驗中已做過4天，因此增加香蕉存放天數後如生成比第四天的香蕉更多的磚紅色沉澱物則能証明存放四天香蕉成熟度不足。

About the samples

- Sample 1 incorrectly believed that using a narrower range and interval of the independent variable could produce positive Benedict's results even though the bananas had not yet ripened.
- Sample 2 correctly suggested lengthening the duration of the storage of the banana which could provide more time for the ripening process.
- Sample 3 further suggested comparing the amount of precipitate in the sample from Day 8 and that in the sample from Day 4.

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

Sample 1

(b) 你的另一位同學發現香蕉成熟第 2 日和第 4 日在本立德試驗下，所觀察到顏色深度非常相似並且沉澱量非常接近。為更準確地判斷兩個樣本的還原糖含量是否有差異，你會建議他怎樣做？

我會建議他用多點的本立德溶液和在放試管久一點去靜置溶液的沉澱及顏色便可以詳細分別兩試管顏色的不同

Sample 2

(b) 你的另一位同學發現香蕉成熟第 2 日和第 4 日在本立德試驗下，所觀察到顏色深度非常相似並且沉澱量非常接近。為更準確地判斷兩個樣本的還原糖含量是否有差異，你會建議他怎樣做？

利用光度計測試吸光度，吸光度更高的含更多沉澱物。

Sample 3

(b) 你的另一位同學發現香蕉成熟第 2 日和第 4 日在本立德試驗下，所觀察到顏色深度非常相似並且沉澱量非常接近。為更準確地判斷兩個樣本的還原糖含量是否有差異，你會建議他怎樣做？

我建議他用吸光計檢測兩個沉澱物，越干的，沉澱物越深色，便可得知還原糖那個動物

或者用電子秤量度兩者沉澱物的份量，越干的沉澱物越多，便能得知兩者還原糖差異

About the samples

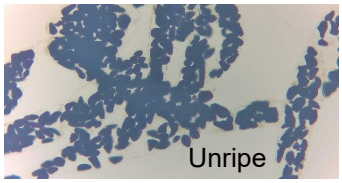
- Sample 1 incorrectly believed that increasing the volume of the Benedict's test and lengthening the time for the Benedict's test could more accurately detect the minute differences in the amount of reducing sugars. Note that the protocol used excess Benedict's solution and heated the samples sufficiently.
- Sample 2 suggested an alternative strategy, the use of a colorimeter to detect the differences in the samples.
- Sample 3 provided two alternative methods. The sample could further improve by providing an explanation for why these methods are more sensitive in detecting the differences.

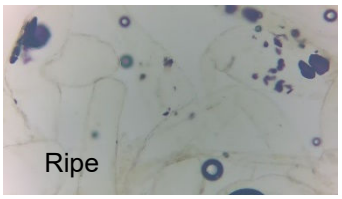
Supplementary Resources

Possible Modifications

1. Preparation of temporary microscope slides of unripe and ripe banana samples

- Gently smear samples of the unripe and ripe bananas onto separate microscope slides.
  (Do *not* use a knife in order to avoid spilling the cellular contents.)
- Instruct students to examine the slides under the microscope.
- See Tamarkin (2015) for a detailed description.





2. Investigating the ripening process of bell peppers

- Green, yellow, and red bell peppers are the same vegetable at different stages of ripeness. Green peppers are unripe while red peppers are fully ripened. Yellow peppers fall somewhere in the middle of the ripening process.
- Bell peppers can be used to study the biochemical changes that occur as a result of the ripening process (e.g., changes in vitamin C, reducing sugar and enzyme content [e.g., catalase]).
- See Olędzki & Harasym (2023) for an example.

Technician Notes

1. Materials for Task 1

Handheld UV light torch	Overripe banana	Black box

2. Materials for Task 4

Materials for each group

Banana from day 0	Electronic balance	Filter funnel
Banana stored for 2 days	Plastic bag	100 mL beaker
Banana stored for 4 days	Muslin cloth	Test tubes
Benedict's solution	Mini water bath	Iodine solution (dropper bottle)
White tile	Knife	Autopipette (P-1000)
Autopipette tip (P-1000)	Rubbish bin	

References

Olędzki, R., & Harasym, J. (2023). Boiling vs. microwave heating—The impact on physicochemical characteristics of bell pepper (*Capsicum annuum L.*) at different ripening stages. *Applied Sciences*, *13*(14), 1–14.

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