

NAVRACHANA INTERNATIONAL SCHOOL VADODARA**IB DP BIOLOGY SL HANDBOOK**

(Information in this document is resourced from IB subject guide and TSM)



Complied by

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Syllabus Outline

Core

Topic 1: Cell biology

- 1.1 Introduction to cells
- 1.2 Ultrastructure of cells
- 1.3 Membrane structure
- 1.4 Membrane transport
- 1.5 The origin of cells
- 1.6 Cell division

Topic 2: Molecular biology

- 2.1 Molecules to metabolism
- 2.2 Water
- 2.3 Carbohydrates and lipids
- 2.4 Proteins
- 2.5 Enzymes
- 2.6 Structure of DNA and RNA
- 2.7 DNA replication, transcription and translation
- 2.8 Cell respiration
- 2.9 Photosynthesis

Topic 3: Genetics

- 3.1 Genes
- 3.2 Chromosomes
- 3.3 Meiosis
- 3.4 Inheritance
- 3.5 Genetic modification and biotechnology

Topic 4: Ecology

- 4.1 Species, communities and ecosystems
- 4.2 Energy flow
- 4.3 Carbon cycling
- 4.4 Climate change

Topic 5: Evolution and biodiversity

- 5.1 Evidence for evolution
- 5.2 Natural selection
- 5.3 Classification of biodiversity
- 5.4 Cladistics

Topic 6: Human physiology

- 6.1 Digestion and absorption
- 6.2 The blood system
- 6.3 Defence against infectious disease
- 6.4 Gas exchange
- 6.5 Neurons and synapses
- 6.6 Hormones, homeostasis and reproduction

Options

A: Neurobiology and behaviour

Core topics

- A.1 Neural development
- A.2 The human brain
- A.3 Perception of stimuli

B: Biotechnology and bioinformatics

Core topics

- B.1 Microbiology: organisms in industry
- B.2 Biotechnology in agriculture
- B.3 Environmental protection

C: Ecology and conservation

Core topics

- C.1 Species and communities
- C.2 Communities and ecosystems
- C.3 Impacts of humans on ecosystem
- C.4 Conservation of biodiversity

D: Human physiology

Core topics

- D.1 Human nutrition
- D.2 Digestion
- D.3 Functions of the liver
- D.4 The heart

Higher level assessment specifications

Component	Overall Weight age	Duration	Format & Syllabus Coverage
Paper 1	20	1 hr	40 multiple-choice questions on the core + AHL material.
Paper 2	36	2 ¼ hr	Data-based question ,short-answer questions and extended-response questions on the core and the AHL
Paper 3	24	1 ¼ hr	Questions on core and SL option material. Section A – short answer question on experimental work Section B - answer and extended-response questions from one option.
Externals	80%		
Internals	20% [Investigations + Group 4 project]		

Practical Work And Internal Assessment
Internal Assessment Specifications 20%

INTERNAL ASSESSMENT CRITERIA

The new assessment model uses five criteria to assess the final report of the individual investigation with the following raw marks and weightings assigned.

Personal Engagement	Exploration	Analysis	Evaluation	Communication	Total
2(8%)	6(25%)	6(25%)	6(25%)	4(17%)	24(100%)

Students at SL are required to spend 40 hours, and students at HL 60 hours, on practical activities (excluding time spent writing up work). These times include 10 hours for the group 4 project and 10 hours for the internal assessment investigation. (Only 2–3 hours of investigative work can be carried out after the deadline for submitting work to the moderator and still be counted in the total number of hours for the practical scheme of work.)

Resources:

➤ **Books**

- Biology for IB diploma SL & HL- Allan Damon [Pearson Baccalaureate]
- Biology for IB diploma SL&HL- Weem
- Advanced Biology –Kent
- Course companion in Biology by Alliot

Internal Assessment Group 4 Sciences ***[Biology, Chemistry & Physics]***

Weighting - 20%

Time – 10 hours

The new assessment model uses five criteria to assess the final report of the individual investigation with the following raw marks and weightings assigned:

Personal Engagement:	2
Exploration:	6
Analysis:	6
Evaluation:	6
<u>Communication:</u>	<u>4</u>
TOTAL:	24

Personal engagement – 2 marks

This criterion assesses the extent to which the student engages with the exploration and makes it their own. Personal engagement may be recognized in different attributes and skills. These could include addressing personal interests or showing evidence of independent thinking, creativity or initiative in the designing, implementation or presentation of the investigation.

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1	The evidence of personal engagement with the exploration is limited with little independent thinking, initiative or insight. The justification given for choosing the research question and/or the topic under investigation does not demonstrate personal significance, interest or curiosity. There is little evidence of personal input and initiative in the designing, implementation or presentation of the investigation.
2	The evidence of personal engagement with the exploration is clear with significant independent thinking, initiative or insight. The justification given for choosing the research question and/or the topic under investigation demonstrates personal significance, interest or curiosity. There is evidence of personal input and initiative in the designing, implementation or presentation of the investigation.

Exploration – 6 marks

This criterion assesses the extent to which the student establishes the scientific context for the work, states a clear and focused research question and uses concepts and techniques appropriate to the Diploma Programme level. Where appropriate, this criterion also assesses awareness of safety, environmental, and ethical considerations.

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1–2	The topic of the investigation is identified and a research question of some relevance is stated but it is not focused. The background information provided for the investigation is superficial or of limited relevance and does not aid the understanding of the context of the investigation. The methodology of the investigation is only appropriate to address the research question to a very limited extent since it takes into consideration few of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of limited awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation*.
3–4	The topic of the investigation is identified and a relevant but not fully focused research question is described. The background information provided for the investigation is mainly appropriate and relevant and aids the understanding of the context of the investigation. The methodology of the investigation is mainly appropriate to address the research question but has limitations since it takes into consideration only some of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of some awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation*.

Mark	Descriptor
5–6	The topic of the investigation is identified and a relevant and fully focused research question is clearly described. The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation. The methodology of the investigation is highly appropriate to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of full awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation*.

Analysis – 6 marks

This criterion assesses the extent to which the student's report provides evidence that the student has selected, recorded, processed and **interpreted** the data in ways that are relevant to the research question and can support a conclusion.

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1–2	The report includes insufficient relevant raw data to support a valid conclusion to the research question. Some basic data processing is carried out but is either too inaccurate or too insufficient to lead to a valid conclusion. The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis. The processed data is incorrectly or insufficiently interpreted so that the conclusion is invalid or very incomplete.
3–4	The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question. Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing. The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis. The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced.

Mark	Descriptor
5–6	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question. Appropriate and sufficient data processing is carried out with the accuracy required to enable a conclusion to the research question to be drawn that is fully consistent with the experimental data. The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis. The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.

Evaluation – 6 marks

This criterion assesses the extent to which the student's report provides evidence of evaluation of the investigation and the results with regard to the research question and the accepted scientific context.

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1–2	A conclusion is outlined which is not relevant to the research question or is not supported by the data presented. The conclusion makes superficial comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are outlined but are restricted to an account of the practical or procedural issues faced. The student has outlined very few realistic and relevant suggestions for the improvement and extension of the investigation.
3–4	A conclusion is described which is relevant to the research question and supported by the data presented. A conclusion is described which makes some relevant comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are described and provide evidence of some awareness of the methodological issues* involved in establishing the conclusion. The student has described some realistic and relevant suggestions for the improvement and extension of the investigation.

Mark	Descriptor
5–6	A detailed conclusion is described and justified which is entirely relevant to the research question and fully supported by the data presented. A conclusion is correctly described and justified through relevant comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are discussed and provide evidence of a clear understanding of the methodological issues* involved in establishing the conclusion. The student has discussed realistic and relevant suggestions for the improvement and extension of the investigation.

Communication– 4 marks

This criterion assesses whether the investigation is presented and reported in a way that supports effective communication of the focus, process and outcomes.

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1–2	The presentation of the investigation is unclear, making it difficult to understand the focus, process and outcomes. The report is not well structured and is unclear: the necessary information on focus, process and outcomes is missing or is presented in an incoherent or disorganized way. The understanding of the focus, process and outcomes of the investigation is obscured by the presence of inappropriate or irrelevant information. There are many errors in the use of subject-specific terminology and conventions*.
3–4	The presentation of the investigation is clear. Any errors do not hamper understanding of the focus, process and outcomes. The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way. The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation. The use of subject-specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding.

A study on the effect of smoke water on the germination and growth of *Eucalyptus pilularis*

Background

Australia is a country where bushfires are commonplace during the summer season, and these fires affect much of Australia's flora. As a by-product of this, numerous native Australian plants that inhabit fire-dependent ecosystems have evolved reproductive strategies to adapt to factors associated with fire. These adaptations that affect their germination can be classified as either physical (derived from the immense heat of the bushfire stimulating a seed to germinate) or chemical (derived from a combination of various chemical elements produced by the smoke that stimulates germination).

Aim

The aim of this biology laboratory experiment is to explore the effects of smoke water, a mixture of water, burnt plants and hay, and its effect on the germination and post germination growth *Eucalyptus pilularis* seeds also known as gumnut or blackbutt, an Australian native plant which predominates in forests that are frequently burned.

Research question

Does smoke water stimulate germination and post germination growth of *Eucalyptus pilularis* seeds compared to de-ionized water?

Prediction

Smoke water will successfully germinate more *Eucalyptus pilularis* than de-ionized water, and thus, as a result of this, the post germination growth of the *Eucalyptus pilularis* seeds by the smoke water will be more effective. Effectiveness, for this experiment, is defined as the height of the seedling that emerges from the germinated gumnut seed. If the various chemicals, such as phosphorous and nitrogenous compounds found in the smoky remnants of organic matter function as chemical triggers, then *Eucalyptus pilularis* will begin its germination out of its dormant state. These phosphorous and nitrogenous compounds, such as NaNO_3 , KNO_3 , NH_4Cl and NH_4NO_3 , that are naturally occurring in organic matter, are not found in de-ionized water (Dixon et al. 1995), and hence, smoke water is predicted to germinate a larger number of seeds and grow more after germination than de-ionized water¹.

Method

Preliminary experiment

The gumnut seeds were obtained from trees growing in local forestry plantations. It was felt necessary to find out if the gumnut seeds would germinate or not.

1. 50 seeds were planted in 5 Petri dishes of potting mixture (10 seeds per dish).
2. Each dish was watered with 10 ml of de-ionised water and left for two weeks at room temperature.
3. At the end of the two weeks the numbers of seeds germinating was counted.

Results

Number of seeds germinating = 22/50

Percentage germination = 44%

The supply of seeds was considered viable enough to proceed with the experiment.

Comm: Overall the report is clear, concise and logically structured.

Comm: Subject specific terminology and notation are used throughout.

PE: Student shows a high degree of engagement with the investigation.

EX: Investigation set in context and justified.

EX: Smoke water defined

EX: Research question focussed

EX: Methodology appropriate

Ex: Defines method to collect relevant data

Ex: Method can be easily followed and repeated by others.

Ex: Anticipates that method may need modifying. Sufficient data is planned for

Ex: Suitable control

An: Data displayed from trial run

An: Appropriate processing

Ev: Conclusion made from trial run.

¹ <http://anpsa.org.au/APOL2/jun96-6.html>

Equipment

- 10 Petri dishes
- 100g of "Yates premium quality" potting mix
- 5.00g of hay
- 5.00g of Eucalyptus leaves
- 5.00g of grass
- Electronic weighing scale ($\pm 0.01\text{g}$)
- 100 seeds of *E. pilularis* that are 2.00 mm in diameter ($\pm 0.5\text{mm}$)
- 10.0cm ruler ($\pm 0.5\text{mm}$)
- 100ml of de-ionized water to create the smoke water
- 100ml of de-ionized water to create the control
- Tea strainer
- 3 x 250ml graduated beaker ($\pm 0.4\text{mL}$)
- Matches
- 2 Sand baths
- 2 thermometers ($\pm 0.05^\circ\text{C}$)

To create the smoke water

1. Place 5g each of the hay, grass and Eucalyptus leaves into one of the 250ml beaker.
2. Ignite the organic matter with a match so that they catch on fire. Let them burn until they are all charred.
3. Measure 100ml of de-ionized water with the second 250ml beakers. Pour this water into the first beaker with the leaves, hay and twigs and leave to infuse for 5 hours.
4. Strain the smoke water mixture into the third measuring beaker using the tea strainer, ensuring that you are only left with the liquid remnants.

SAFETY Care should be taken when burning the organic matter, this should be carried out in a ventilated area and the beakers should be made of heat resistance glass.

Ex: Safety risks assessed

Germination and growth

1. Set the sand baths to 30 degrees Celsius and place a thermometer in each one to verify the temperature setting.
2. Place 5 Petri dishes into one sand bath and the remaining 5 Petri dishes into another. One will be our control and one will be our test.
3. Measure out 10 x 10.0g of the potting mix using the electronic weighing scale and place 10.0g into each one of 10 Petri dishes. 5 dishes for smoke water treatment and 5 dishes for de-ionised water treatment.
4. Sow 10 gumnuts into each Petri dish and submerge them into the potting mix at a consistent depth of 0.5cm. Place the seeds towards the edges of the Petri dish so they can be observed through the glass without having to disturb the seeds to observe them.
5. Water the control sand bath at 8:15am with 10ml of de-ionized or smoke water each day for fourteen days.
6. After 14 days, count the number of seeds germinated (distinguished by the emergence of the seedling) and measure the height of the emergent seedling in the test and the control groups with the 10.0cm ruler. The seedling height is measured from the soil surface to the highest part of the stem.
7. Repeat the set up once to ensure sufficient data.

Ex: Plans for sufficient data

Ex: Plans for sufficient data

Comm: Correct definition of germination

Ex: Plans for sufficient data

Controlled Variables

- The same volume (10ml) of liquid is added to each dish at the same time (8:15am) each day throughout the 14 days.
- All 100 *E. pilularis* seeds that were used in this experiment were kept within a size range of 2.00 mm in diameter
- The water used to create the smoke water was de-ionized water like the control, which allowed consistency between the control and the test groups.

Ex: Thorough consideration of the other factors that may influence the investigation

- The temperature of the seeds was kept constant at 30.0°C by the sand baths.
- The potting mix for the seeds was from the same brand, "Yates premium potting mix" and the mass of potting mix used for the seeds was kept constant at 10.0g.
- Same amount of light was assumed to be received for each plant as the experiment was conducted in the same location on the same days.
- The seeds were placed at a depth of 0.5cm into the soil in the Petri dish.

The experiment continued for fourteen days to allow for sufficient time to gauge of the effect of the different water types, the manipulated variable. Both sand baths set at the same temperature are placed next to each other, as specified by the method, and they are assumed to be receiving equal amounts of light. The potting mix was taken from the same batch, so all samples could be assumed to contain the same ratio of ingredients. Furthermore, the *E. pilularis* was submerged into the potting mix at a consistent depth of 0.5cm and towards the edges of the Petri dish to allow for observations to be made through the glass without having to disrupt the seeds to observe them.

Our method of data collection for this experiment is to count the seeds that successfully germinated from the different Petri dishes in the control and test groups respectively, the measured variable. This is done by observing through the side of the Petri dish whether the seed coat has broken and the seedling has emerged. The other way to collect data in this experiment is to measure the height of the seedlings (from the soil surface to the seedling tip) of the germinated seeds after the 14 days of the experiment. The difference between smoke water and de-ionised water was determined using the χ^2 test for the germination and the t-test for the growth of the seedlings.

An: Appropriate method of analysis chosen

Assumptions

- The light is of the same intensity because the seeds will be set up side by side.
- The de-ionized water contains the same impurities
- The potting mix contains the same amount of its constituent components.
- The impurities and chemical elements in the air will be the same for both sets of seeds.
- The gumnut seeds are all composed of the same percentage of elements.

Observations

- The *E. pilularis* seeds were no bigger than 2mm, and were brownish black in colour. There were no obvious signs of previous germination, or cracking of the outer seed coat.
- The smoke water was clearly distinctive from the de-ionized water. The de-ionized water was clear, as one would expect if it had been filtered. The smoke water, however, had a blackish, straw coloured hue, due to its absorption of the remnants of the burnt organic matter.
- Definite germination was seen on a lot more seeds with the smoke water than with the de-ionized water.
- The *E. pilularis* subjected to smoke water germinated earlier on average than the seeds subjected to de-ionized water. Seeds with smoke water started showing first signs of germination as early as 7 days, when their seed coats started to split to allow the seedlings to emerge. In comparison, the de-ionized watered seeds took up to 10 days to start showing germination.
- The *E. pilularis* that were germinated by the smoke water tended to have larger seedlings emerging from the split seed coat.
- The *E. pilularis* that were watered with the smoke water had significantly larger cracking of the seed coat, allowing for more space for the seedlings to grow and extend outwards from the shell.
- The colour of the seedlings in both experiments was a distinct dark purple colour, and leaves appeared only on the smoke water experiment, with a maximum of 2 small, juvenile leaves found, measuring no more than approximately 50.0mm.

An: Adequate qualitative observations made

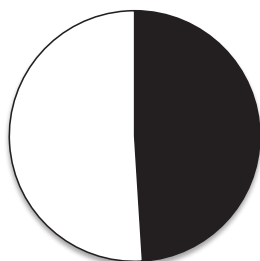
Number of seeds successfully germinated

In order to determine the number of seeds that were germinated successfully, the number of seeds that showed distinct cracking of the seed coat and the emergence of the seedling for both the smoke water and the de-ionized water test groups were counted and placed into the table below. The raw data is presented in appendix A.

Water Type	Trial	Numbers germinated (/50)	Average	%
De-ionized	1	26	25	49
	2	23		
Smoked	1	43	44	88
	2	45		

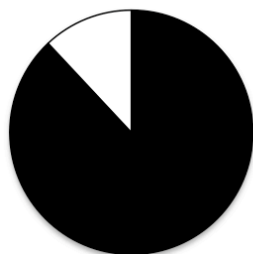
From the processed data that informs us about the number of seeds successfully germinated, we can clearly see that smoke water germinates, on average.

Graph of de-ionised water seed germination



- Percentage de-ionised water gumnut seeds germinated
- Percentage de-ionised water gumnut seeds NOT germinated

Graph of smoke water seed germination



- Percentage smoke water gumnut seeds germinated
- Percentage smoke water gumnut seeds NOT germinated

Comm: Data table set in context. Clear, unambiguous presentation

Comm: Data analysis can be followed (no need for a worked example here)

An: Uncertainties missing but not considered relevant here for a count. However uncertainties $\pm 2\%$ could have featured for the percentage germination data.

An: Appropriate graphical presentation of processed data

Comm: Clear presentation of graph

X² test

In order to see if there is a significant difference between the germination of the seeds treated with smoke water and de-ionised water a X² test was carried out.

Null Hypothesis: Smoke water does not affect germination of gumnut seeds

Alternative Hypothesis: Smoke water affects germination of gumnut seeds

	Smoke water	De-ionised water	Row total
Germinated	88	49	137
Not germinated	12	51	63
Column total	100	100	200

Proportion of seed germinating = $137/200 = 68.5\%$

Proportion of seeds not germinating = $100 - 68.5 = 31.5\%$

Expected number of smoke water treated seeds to germinate = 68.5% of $100 = 68.5$

Expected number of de-ionised water treated seeds to germinate = 68.5% of $100 = 68.5$

Expected number of smoke water treated seeds not to germination = 31.5% of $100 = 31.5$

Expected number of de-ionised water treated seeds not to germinate = 31.5% of $100 = 31.5$

Observed frequency	Expected frequency	Difference	Positive difference	
O	E	O-E	IO-EI	$(IO-EI)^2/E$
88	68.5	19.5	19.5	5.55
49	68.5	-19.5	19.5	5.55
12	31.5	-19.5	19.5	12.07
51	31.5	19.5	19.5	12.07
			X ² _{calc}	35.25

Number of degrees of freedom = $(\text{rows} - 1) \times (\text{columns} - 1) = (2-1) \times (2-1) = 1$

X²_{crit} = 3.84 for p=0.05

Since the test value for X²_{calc} = 35.25 is a lot greater than the critical value X²_{crit} = 3.84 we must reject the Null Hypothesis and accept the Alternative Hypothesis. The test value is significant for $p < 0.001$

Comm: Data processing can be followed.

An: Processed data correctly interpreted

An: Successful data analysis completed. Conclusion can be deduced.

The effect of smoke water and de-ionized water on post germination growth

This section of the experiment is designed to test the effectiveness of gumnut seed germination, depending on the type of water it received, either de-ionized or smoke water. Effectiveness was determined by the height of the seedling that emerged from the seed coat of the germinated gumnut seeds. The higher the seedling the more effective the water is **on germination**. The raw data is presented in appendix A.

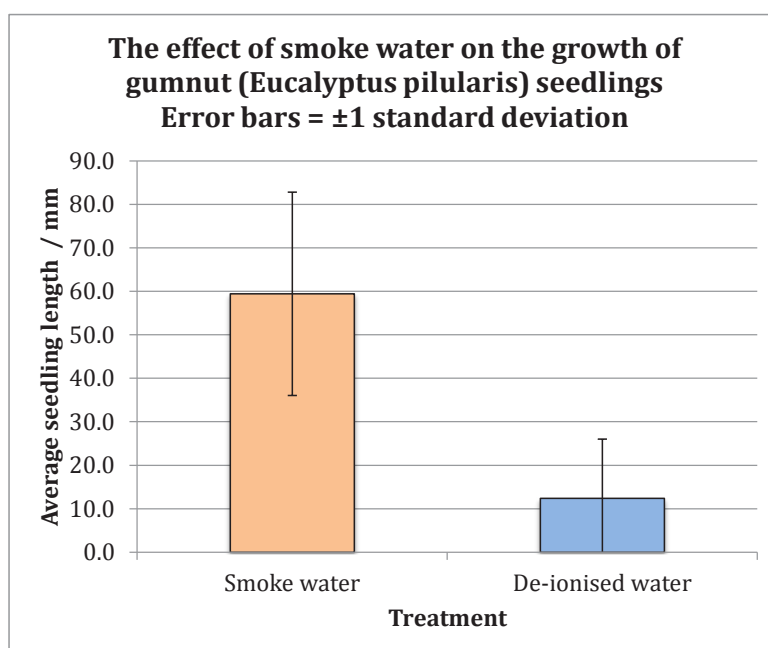
Height of seedlings for germinated seeds					
Water Type	Trial	Trial average of seedling height /mm $\pm 0.5\text{mm}$	Trial Standard Deviation	Overall average height /mm $\pm 0.5\text{mm}$	Overall standard deviation
De-ionized	1	13.0	13.4	23.4	13.6
	2	11.8	13.9		
Smoked	1	57.8	24.5	59.5	12.4
	2	61.1	22.3		

Comm : Terminology is imprecise here. Strictly speaking this is post germination growth

Comm: Data table set in context. Clear, unambiguous presentation. Processing can be followed, a worked example is not expected here. Processing can be followed. Correct conventions for uncertainties

On first observation of the processed data, it can be seen that smoked water clearly has a higher average seedling height than the de-ionized water whilst also having a lower standard deviation. This indicated that the smoked water seeds seedling grew higher than the de-ionized water. The error bars in the graph below suggest that there may be a significant difference between the affects of the treatment on seedling growth. However, the range of variation in the results as given by the standard deviations is large especially for the de-ionised water treatment trials. To verify this, a t-test was carried out on the data.

An: The candidate considers the reliability of the data though it could be argued that ungerminated seeds should not be included here. These results (0cm growth) skew the distribution so that it is not normally distributed.



t-test

In order to statistically test whether the shoot of smoke water germinated gumnut seedlings grew more than the de-ionized water, a two-tailed t-test for independent samples was carried out to investigate whether there is a significant difference between the growth of the seedlings.

- **Null Hypothesis** - the smoke water has no effect on post germination growth of the gumnut seedlings.
- **Alternative Hypothesis** - the smoke water does have an effect on post germination growth of the gumnut seedlings.

t-test formula:

$$t = \frac{|\bar{X}_1 - \bar{X}_2|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

degrees of freedom = $n_1 + n_2 - 1 = 198$

$t_{\text{calc}} = 17.4$

$t_{\text{crit}} (p=0.05) = 1.97$

Because our test t value $t_{\text{calc}} = 17.4$ is greater than the critical value $t_{\text{crit}} = 1.97$ at $p = 0.05$, we can accept the alternative hypothesis, that the smoke water significantly stimulates the growth of the gumnut seedlings germinated. The test value is significant for $p < 0.001$

An: Appropriate method of analysis chosen.

Comm: Processing can be followed.

An: Successful data analysis and interpretation completed

Ev: Student considers the reliability of the data and considers the impact of experimental uncertainty

Ev: Sensible suggested improvement.

Evaluation of Weaknesses with suggested improvements

The potting mixture used was obtained from the local garden shop, and whilst the same brand and the same amount of the potting mixture was used for both seeds in the experiment, the potting mixture may have contained impurities which could potentially have enhanced or reduced the ability of the seeds to germinate, especially because the Yates brand "Contains trace elements to add extra vital nutrients"². Some of the chemicals from the smoke water also could have potentially reacted with some of the ingredients of the potting mix and rendered them useless, however the seeds watered with de-ionized water may not have had this potential problem. To improve this, I could have used a different support for the seeds such as cotton wool or filter paper.

Using different types of leaves, twigs and hay to create the smoke water would give you different chemicals, as each has a differing composition of chemicals, some of which may be beneficial for germination, and some of which wouldn't. For this experiment, I could have used only one variable like hay, instead of twigs and leaves as well. This would narrow my scope of results down as well and I would potentially be able to pinpoint the specific chemical, or source of the chemical, that allows gumnuts to germinate successfully. It may be found that twigs, for example, don't enhance seed germination but leaves do. By singling out the element that best enhances seed germination, further experiments could be carried out, and the exact chemical could be identified, that best enhances the seeds germination.

Ev: Feasible extension proposed.

Combined with this, I could have used gumnut seeds that were all the same weight rather than the same size in diameter. I tried to use gumnut seeds that were only 2.00mm in diameter, however it would have been better served to use seeds that all had a constant weight of 0.2g for example, as then I could have assumed that each seed contained the same amounts and composition of nutrients, enzymes and other chemicals inside it.

Ev: Suggested improvement impractical

Ev: Unsafe assumption

To further narrow my scope of the experiment, I could have tested the effects of different concentrations of the smoke water as well. Instead of only using a 1:10 ratio of 1 part twigs, hay and leaves to 10 parts de-ionized water, I could have tested a ratio of 1:5 with 1 part twigs, hay and leaves and 5 parts de-ionized water. Working out the optimum concentration of smoke water would help this experiment as better and clearer results could be obtained.

Ev: Feasible extension proposed.

²<http://www.yates.com.au/products/pots-and-potting-mix/all-purpose-potting-mix/yates-premium-potting-mix/>

Conclusion

In conclusion, the experiment supported my hypothesis that smoke water will successfully germinate more *Eucalyptus pilularis* than de-ionized water. Furthermore, the subsequent growth of the *Eucalyptus pilularis* seeds by the smoke water was found to be more effective than the de-ionized water due to the significantly taller seedlings of the *Eucalyptus pilularis* that were exposed to the smoke water. This could be because the various chemicals, such as phosphorous and nitrogenous compounds found in the smoky remnants of the burnt organic matter (in my case, the burnt leaves, hay and twigs) acted as chemical triggers for the *E. pilularis* to begin its germination out of its dormant state and stimulate its subsequent growth. While all of the active compounds in smoke have not yet been identified, a large majority of the compounds present in the smoke water mixture (NaNO_3 , KNO_3 , NH_4Cl and NH_4NO_3) are water soluble, thus they are easily able to be taken in by the gumnut seed and, once inside the seed, they are used as these so called "chemical triggers" to start germination. These chemical triggers work by altering the levels of chemicals that the seed maintains in homeostasis, once the seed has registered these differing levels of phosphorous and nitrogenous compounds, it stimulates the germination of the seed. There are, however, compounds called *butenolides* that have confirmed germination-promoting action. These *butenolides* are produced by some plants on exposure to high temperatures and smoke caused by bush fires. In particular, botanists Flematti, Ghisalberti, Dixon and Trengove isolated a particular *butenolide* called 3-methyl-2H-furo[2,3-c]pyran-2-one, which was found to trigger seed germination in plants whose reproduction is fire-dependent, such as the *E. pilularis* used in my experiment³. One theory about how this *butenolide* called 3-methyl-2H-furo[2,3-c]pyran-2-one is formed by the plant is given to us by Light, Berger and van Steden, who hypothesized that this particular *butenolide* was created from cellulose within the plant, and this substance, created by the cellulose, stimulated the seeds reproductive cycle, and hence, germination⁴. The two pie graphs that show the percentage of seeds germinated for the smoke water experiment and de-ionized water experiment respectively, furthermore indicate that my hypothesis was correct, with 88% of the smoke watered seeds successfully germinating compared to only 47% of the de-ionized water seeds germinating. This was backed up with my χ^2 -test that accurately concluded that we could reject the null hypothesis, with a 95% degree of confidence, that the smoke water successfully germinated more seeds than the de-ionized water. The t-test on the seedling growth shows that the smoke water has a significant positive effect on the gumnut seedlings.

Ev: Compare to relevant scientific theory

Ev: Successful interpretation of the results. Relevant justified conclusion drawn

Bibliography

Yates Gardening Ltd Sydney Australia <http://www.yates.com.au/products/pots-and-potting-mix/all-purpose-potting-mix/yates-premium-potting-mix/> Last visited July 10 2011

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Marnie E. Light, Barend V. Burger and Johannes van Staden Formation of a Seed Germination Promoter from Carbohydrates and Amino Acids <http://pubs.acs.org/doi/abs/10.1021/jf050710u> J. Agric. Food Chem., 2005, 53 (15), pp 5936–5942 Publication Date (Web): July 1, 2005

³ <http://www.sciencemag.org/content/305/5686/977>

⁴ <http://pubs.acs.org/doi/abs/10.1021/jf050710u>

Appendix A - raw data tables

Seeds watered with Smoke Water (Trial 1)

Seed Number	Did the seed Germinate	Height of seedling in / mm ± 0.5 mm
1	Yes	56.0
2	Yes	71.0
3	Yes	73.0
4	Yes	67.0
5	Yes	54.0
6	No	0
7	Yes	58.0
8	Yes	70.0
9	Yes	66.0
10	Yes	61.0
11	Yes	64.0
12	Yes	71.0
13	No	0
14	No	0
15	Yes	59.0
16	Yes	67.0
17	Yes	58.0
18	Yes	63.0
19	Yes	62.0
20	Yes	64.0
21	Yes	72.0
22	Yes	75.0
23	No	0.0
24	Yes	68.0
25	Yes	64.0
26	Yes	69.0
27	Yes	70.0
28	No	0
29	Yes	52.0
30	No	0
31	Yes	79.0
32	Yes	81.0
33	Yes	83.0
34	Yes	74.0
35	Yes	74.0
36	Yes	78.0
37	Yes	63.0
38	Yes	69.0
39	Yes	58.0
40	Yes	70.0
41	Yes	68.0
42	Yes	62.0
43	Yes	63.0
44	Yes	68.0
45	Yes	58.0
46	Yes	81.0
47	Yes	68.0
48	Yes	73.0
49	Yes	67.0
50	No	0

An: Raw data recorded includes uncertainties

Comm: Decimal places should be consistent

Seeds watered with De-ionized water (Trial 1)

Seed Number	Did the seed Germinate	Height of seedling in / mm $\pm 0.5\text{mm}$
1	Yes	18
2	Yes	27.0
3	Yes	19.0
4	No	0
5	No	0
6	No	0
7	Yes	24.0
8	No	0
9	Yes	25.0
10	No	0
11	Yes	28.0
12	No	0
13	No	0
14	Yes	17.0
15	Yes	23.0
16	No	0
17	Yes	16.0
18	No	0
19	Yes	26.0
20	Yes	27.0
21	Yes	15.0
22	No	0
23	No	0
24	Yes	27.0
25	No	0
26	Yes	21.0
27	Yes	22.0
28	No	0
29	Yes	27.0
30	Yes	37.0
31	No	0
32	No	0
33	Yes	26.0
34	Yes	31.0
35	No	0
36	No	0
37	Yes	27.0
38	Yes	41.0
39	No	0
40	No	0
41	No	0
42	Yes	25.0
43	No	0
44	Yes	19.0
45	No	0
46	No	0
47	Yes	37.0
48	Yes	22.0
49	No	0
50	Yes	25.0

Seeds watered with Smoke water (Trial 2)		
Seed Number	Did the seed Germinate	Height of seedling in mm / $\pm 0.5\text{mm}$
1	Yes	72.0
2	Yes	73.0
3	No	0
4	Yes	72.0
5	Yes	57.0
6	Yes	74.0
7	Yes	79.0
8	Yes	62.0
9	Yes	78.0
10	Yes	64.0
11	Yes	72.0
12	Yes	79.0
13	Yes	72.0
14	Yes	57.0
15	Yes	56.0
16	Yes	83.0
17	Yes	63.0
18	No	0
19	Yes	72.0
20	Yes	63.0
21	No	0
22	Yes	58.0
23	Yes	81.0
24	Yes	57.0
25	Yes	62.0
26	No	0
27	Yes	74.0
28	Yes	73.0
29	Yes	83.0
30	Yes	58.0
31	Yes	74.0
32	Yes	57.0
33	Yes	63.0
34	Yes	79.0
35	Yes	60.0
36	Yes	74.0
37	Yes	79.0
38	Yes	57.0
39	Yes	86.0
40	Yes	53.0
41	Yes	56.0
42	Yes	67.0
43	Yes	63.0
44	Yes	68.0
45	Yes	54.0
46	Yes	68.0
47	Yes	68.0
48	No	0
49	Yes	62.0
50	Yes	72.0

Seeds watered with De-Ionized water (Trial 2)

Seed Number	Did the seed Germinate	Height of seedling in / mm $\pm 0.5\text{mm}$
1	No	0
2	Yes	26.0
3	Yes	21.0
4	Yes	23.0
5	No	0
6	No	0
7	No	0
8	No	0
9	Yes	31.0
10	No	0
11	Yes	14.0
12	No	0
13	No	0
14	Yes	16.0
15	Yes	18.0
16	No	0
17	No	0
18	No	0
19	Yes	26.0
20	Yes	31.0
21	Yes	25.0
22	No	0
23	No	0
24	Yes	21.0
25	No	0
26	Yes	31.0
27	Yes	26.0
28	No	0
29	Yes	23.0
30	Yes	36.0
31	No	0
32	No	0
33	Yes	14.0
34	Yes	23.0
35	No	0
36	No	0
37	Yes	23.0
38	Yes	27.0
39	No	0
40	No	0
41	No	0
42	Yes	24.0
43	No	0
44	Yes	45.0
45	No	0
46	No	0
47	Yes	42.0
48	Yes	23.0
49	No	0
50	No	0

Purpose

My interest in the ripening of fruit developed from an observation that fruits bought in my local supermarket do not always ripen effectively. This stimulated me to find out more about the process of ripening in fruits. I chose nectarines as my material because they were in season and they seemed to be the worst affected by the problem of ripening.

PE: The purpose is clear and the candidate justifies the choice of the research question.

Research Question

How do two different methods of fruit ripening affect the metabolism of starch to glucose in nectarines (*Prunus persica*) over 7 days?

Ex: Research question stated but it could be made more focussed by reference to the ripening methods used.

Introduction

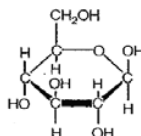


Figure 1 Glucose molecule

Glucose is one of the most important carbohydrates in biochemistry and is pivotal in the key biological processes of photosynthesis and cellular respiration. In the ripening process, starch molecules (polysaccharides) are broken down by digestive enzymes to glucose (monosaccharide). This process is made possible by the induction of ethene gas.²³ Ethene gas is biological hormone that is used in plants to stimulate key processes, for example the germination of seeds, fruit abscission and the ripening process. It is more readily produced by some fruit, in particular bananas and apples, and will hasten the ripening of fruit when in a contained environment, for example inside a plastic bag or box. Another method suggested is to bury the fruit in rice. It is supposed to retain the ethylene gas produced by the fruit longer.⁴

Ex: Relevant background context.

This experiment aims to simulate three different ripening conditions, all of which are presumed to induce the ripening process. In the first trial, a banana will be placed with a nectarine in a closed bag. In the second, a nectarine will be placed under rice in a plastic box. Thirdly, a control whereby a nectarine is placed alone in a plastic bag, will be set up as the null hypothesis, supporting the assumption that the production of ethene gas and the concentration of glucose are independent of one another. It is important that all three trials be conducted in closed environments, which favour the retention of ethene gas.

Ex: Good methodology. Controlled experiment.

The presence of glucose has been used in this experiment to indicate the extent to which ethene gas has affected the metabolism of starch and the concentration of simple sugars in nectarines.

The detection of glucose concentration is possible through the use of a coloured indicator composition of potassium permanganate (KMnO_4) solution and an acid, in this case sulphuric acid (H_2SO_4). A strong oxidising agent, KMnO_4 solution is used to convert alkenes to glycols and thereby quantitatively test for the presence of unsaturated bonds within a sample. The KMnO_4 solution is pink in colour and its discolouring demonstrates the metabolism of starch to glucose.

Ex: safety needs to be considered (see page 4)

Ex: Does not consider the presence of other organic molecules that may get oxidised.

¹<http://mwsu-bio101.ning.com/profiles/blogs/the-molecules-within-you-1>

²<http://www.newton.dep.anl.gov/askasci/bot00/bot00553.htm>

³J.H.LaRue & R.S.Johnson (1989) Peaches Plumbs and Nectarines U Cal Google Books

http://books.google.fr/books?id=0EEtgcbJaAIC&pg=PA163&lpg=PA163&dq=starch+in+nectarines&source=bl&ots=8lab1znGzd&sig=bjD1Nk0gCGTwj3zlbRenFibREms&hl=en&sa=X&ei=wzo6T_C3LYfL0QW_Kk42QCw&redir_esc=y#v=onepage&q=starch%20in%20nectarines&f=false

⁴Matthew Rogers 14/06/11 <http://lifehacker.com/5811686/ripen-fruit-faster-by-burying-it-in-rice>

The time taken for the pink colour to disappear is demonstrative of the concentration of glucose in the filtrate sample, e.g. the smaller the amount of time taken for the colour to disappear, the higher the concentration of glucose in the sample.

Prediction

It is expected that the nectarines exposed to the rice packaging trial will ripen the fastest. The contained environment in which they are placed will favour the retention of ethene gas around the nectarine. As a result, there will be a faster decrease in the concentration of polysaccharides (starch) and a faster increase in the concentration of monosaccharides (glucose) in this trial. The nectarines kept with the banana will also ripen faster than the control as the ethane produced by the banana will supplement that produced by the nectarines themselves.

Comm: This could be a typo as elsewhere "ethane" is used correctly.

Method

Materials

- 36 nectarines
- 12 bananas
- Snap lock bags, plastic containers
- Basmati Rice (approximately 3kg)
- 560ml Sulphuric Acid 1M (H_2SO_4)
- 230ml Potassium Permanganate solution 0.01M (KMnO_4)
- Knife, cutting board, food processor, sieve
- Stop watch
- Syringes - 3ml, 5ml and 10ml
- 4x 750ml beaker (each repeat)
- 12x 50ml beaker (each repeat)

This experiment aims to determine how ethene gas affects the concentration of glucose in nectarines. In order to come to a conclusion, two common methods of fruit ripening, i.e. banana packaging and rice packaging, were tested together with a control. The methods below correspond to these different conditions.

Due to the subjective nature of the 'end point' of the solution, i.e. when the pink colour disappears and the stop-watch is stopped, it was decided that measures should be taken to eliminate as much as possible this error. On each day of the different conditions (banana, rice and control), 4 nectarines were pulverised and effectively, tested. The filtrate of each nectarine was tested three times. This was done so as to eliminate any error that might be associated to the - stirring of the solution and avoid disparity in the results.

Ex: Limitations considered

Ex: Adequate number of repeats but "any error" will not be eliminated

On Day 1 of the experiment the following were set up:

- (a) one banana and one nectarine were placed into a snap-lock bag. The air inside the bag was removed and the bag was sealed
- (b) one nectarine was placed into a plastic box. The container was filled with rice until the nectarine was fully covered and the box was sealed
- (c) one nectarine was placed into a snap-lock bag. The air inside the bag was removed and the bag was sealed.

This was repeated in four trials for each treatment.

One untreated nectarine was retained on Day 1 to establish the initial glucose levels.

Ex: Sufficient trials during the runs considering the manipulation required in this investigation

The fruit were left for 3, 5 or 7 days in room temperature conditions. At the end of the period the

Ex: This should have been trialled more than once.

nectarines were removed and qualitative observations and measurements of the glucose levels were made in the following way.

1. The flesh of the nectarine was removed and placed into a food processor. 500ml of distilled water were then placed in the same processor and pulsed for 30 seconds. The liquid was filtered, through a sieve, into a 750ml beaker.
2. 10ml of the nectarine filtrate was placed into a 50ml beaker. In addition to this, 2ml of KMnO_4 solution and 5ml of H_2SO_4 solution were added into the beaker simultaneously. The stopwatch was started immediately. The solution was swirled in a constant motion and at a constant speed.
3. When the pink colour of the solution had disappeared, the stopwatch was stopped and the time taken was recorded.
This was repeated three times from the filtrate from each nectarine.

Ex: Considers factors that may influence data collection

Ex: Considers factors that may influence data collection

Variables

Variable	Identify variable	How to control variable
Independent	Conditions that the nectarines are exposed to, i.e. banana packaging, rick packaging and controlled environment	
Dependent	Time taken for the pink colour of potassium permanganate solution to disappear (demonstrative of glucose concentration)	
Controlled	Source and age of nectarines	All the nectarines were picked on the same day and sourced from the same supplier. When chosen, it was observed that they were of similar colour, size and firmness.
	Source and age of bananas	All the bananas were picked on the same day and sourced from the same supplier. When chosen, it was observed that they were of similar colour, size and firmness.
	Indicator composition	Remained constant. The ability of KMnO_4 solution to react with impurities meant that the same solution had to be maintained throughout trials.
	Same concentration of KMnO_4 and H_2SO_4	Ensures consistency. Pour a standard solution at beginning of experiment and use throughout
	Initial concentration of glucose	One nectarine was tested and used as an initial value. This value was used across all my trials.
	Nectarine sample	The entire nectarine flesh was pulverized to a filtrate on all repeats.
	Judgement of end point	The 'end-point' of the experiment had to be decided on. Therefore same person had to conduct the experiment to ensure valid results.
	Constant temperature	Temperature affects enzyme activity, i.e. will affect the rate of ripening. Conduct experiment in closed environment.
	Closed environment	Mold and other microorganisms require oxygen to grow, therefore, restricting the amount of oxygen in samples will restrict the development of mold.

Ex: Good appreciation of the controlled variables. Considers factors that may influence data collection.

Risk Assessment

All apparatus was labelled with relevant information (name, date class nature of materials and experiment)

All unnecessary materials were cleared away from the work space.

Glassware is fragile it was used towards the centre of the bench with stable supports.

Sharp cutting tools and the blender were used with care.

Electrical apparatus

The connections of the balance, magnetic stirrer and blender, were kept away from running water and trailing cables were avoid

Spills were cleaned up

Chemicals

Sulphuric acid is corrosive and toxic.

KMnO₄ is a powerful oxidiser and can cause fires.

Eye protection, gloves and lab jacket were worn when handling these chemicals.

Ex: Risk assessment carried out.

Results

Table showing the observations of the three methods on the ripening process

	Banana	Rice	Control
Day 1	One nectarine was used for all of the trials to ensure that the initial concentration of all the repeats was constant. All nectarines on Day 1 were firm, white/yellow in colour and had no visible mould on their surfaces.		
Day 3	Nectarines 1 and 4 showed signs of developing mould. The bananas of these nectarines were discolouring and condensation was visible inside the snap lock bags.	Nectarines were 90-100% covered by the rice. There was minimal condensation inside the box. No mould present.	No mould. No condensation. White/yellow in colour. Firm.
Day 5	All nectarines were softer. Signs of mould. White residue on nectarine 4. Flesh was noticeable darker. Condensation inside of bag.	All nectarines were mouldy, with nectarines 2 and 4 showing the largest mould colonies. White residue. Condensation inside the box. Nectarines were mostly covered by rice, one nectarine was only 75% covered.	No mould. Minimal condensation. Pinkish in colour.
Day 7	All nectarines are at least partially covered by mould and are emitting white residue.	All nectarines at least 9.0% covered in mould. The flesh is a deep brown colour. White residue.	Pink and white in colour. No mould. 'Bruising' patches (soft spots on surface).

An: Good qualitative observations
Comm: Concise & unambiguous table

An: This looks a bit more precise than is possible.

An: What is this referring to? This could be clearer.

Table showing the amount of time taken for the pink colour of the potassium permanganate solution to disappear

Day	Time for KMnO_4 colouration to disappear / s $\pm 0.05\text{s}$											
	Banana				Rice				Control			
	1	3	5	7	1	3	5	7	1	3	5	7
Trial 1	76.23	52.37	47.00	33.03	76.23	56.09	30.57	56.78	76.23	54.33	47.13	36.96
		52.98	48.87	34.31		54.59	31.00	57.23		54.67	46.98	36.78
		52.66	47.96	35.97		54.35	30.76	57.13		55.13	47.96	35.98
Trial 2		54.34	48.28	44.53		50.50	30.19	25.19		54.78	46.56	37.23
		55.65	47.88	45.66		49.86	28.20	26.63		54.65	46.78	37.65
		54.23	48.53	45.17		50.06	29.37	24.78		55.07	46.99	37.98
Trial 3		54.75	47.76	44.27		48.98	29.22	26.78		55.02	47.12	36.87
		54.17	48.22	43.18		49.43	30.45	25.87		55.34	47.56	36.45
		54.23	47.89	44.73		49.56	30.76	26.98		54.69	47.32	36.22
Trial 4		53.98	45.66	38.97		56.33	28.25	57.43		54.79	46.98	36.87
		54.37	46.76	39.24		57.19	27.91	56.91		54.99	47.51	36.98
		54.21	46.23	39.58		56.74	27.65	56.50		55.34	47.35	36.56
Mean	76.23	54.00	47.59	40.72	76.23	52.81	29.53	41.52	76.23	54.90	47.19	36.88
St Dev	0.00	0.91	0.97	4.50	0.00	3.32	1.25	16.18	0.00	0.30	0.38	0.56

An: Relevant quantitative data collected

Comm: Concise, unambiguous & conventions respected

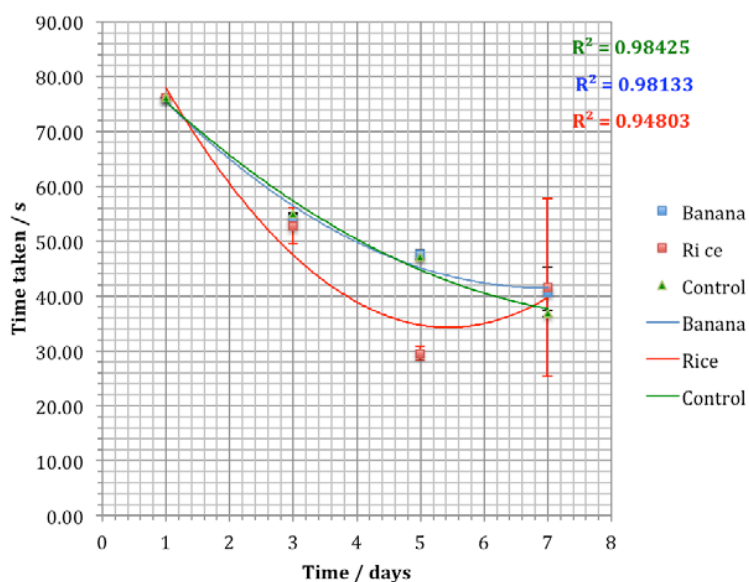
An: Appropriate, successful processing. Uncertainties considered

Comm: Processing can be followed. Correct notation and conventions used.

N.B There is only one value for Day 1 as only one nectarine was used to test for the initial concentration of glucose. This value was used as the initial value (Day 1 value) for all of the subsequent trials.

An: As stated in method this is weak.

Time taken to decolorise KMnO_4 by extract of nectarines incubated with banana, rice or nothing. Error bars = ± 1 standard deviation



Comm: Concise presentation of processed data. Processing can be followed (colour coded R^2 values). Unambiguous (title, key used, colour code used). Correct notation and conventions used.

An: Appropriate processing. R^2 values. Uncertainties presented as trend line, error bars and R^2 values

t-test

The data for the banana treatment and the control do not show much difference for the time taken except after 7 days. The control looks as though it has a higher glucose content than the banana treatment at Day 7. I decided to see if this difference was significant.

An: Appropriate method of analysis

Null Hypothesis = there is no difference between the results for the banana treatment and the control on Day 7

Alternative Hypothesis = There is a difference between the results for the banana treatment and the control on Day 7

t-test equation

$$t = \frac{|\bar{X}_1 - \bar{X}_2|}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

$t_{\text{calc}} = 2.93$

For $p = 0.05$ using a two tailed test

$t_{\text{crit}} = 2.07$

Comm: Processing can be followed

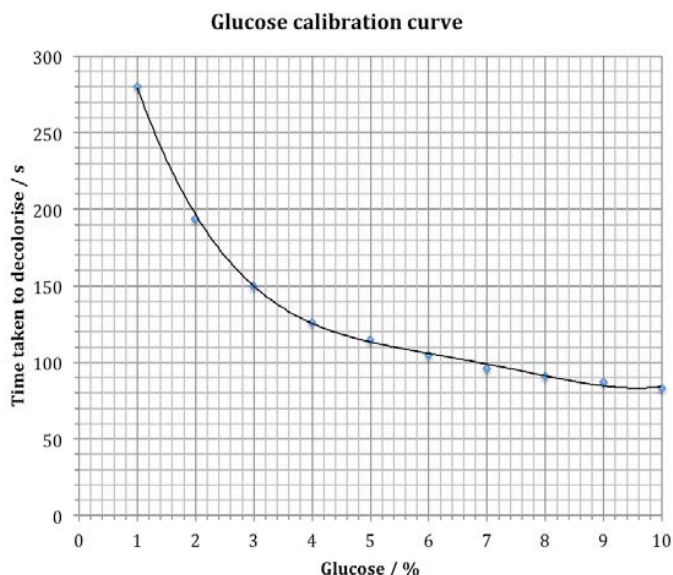
There for there is a significant difference the alternative hypothesis is retained the null hypothesis is rejected. However, this difference is not great, it is only significant to $p = 0.01$

An: Processing successful

Standard Reference Curve for Glucose Concentration**Glucose calibration**

Glucose / %	Time taken / s $\pm 0.05s$
1	280.00
2	194.00
3	150.00
4	126.00
5	115.00
6	105.00
7	96.00
8	91.00
9	87.00
10	83.00

Comm: Correct notation and conventions used



Unfortunately the data obtained was outside of the range of the standard curve so curve could not be used to obtain an estimate of the glucose content of the filtrate.

Comm: Context unambiguous

Error and Limitations

It was acknowledged that the method for this experiment contained certain flaws and that the results obtained from the trials were subject to error. Error-reducing methods were implemented where possible.

An: Uncertainties considered

Uncertainties were accounted for and are recorded below:

Identify uncertainty	Degree of uncertainty
Stopwatch	Reaction time ± 0.05 s
3ml syringe	± 0.1 ml
5ml syringe	± 0.1 ml
10ml syringe	± 0.2 ml
Beakers	± 1.0 ml

Comm: Correct notation and conventions used

Because the glassware used in the experiment was not altered from trial to trial, the level of uncertainty in each trial would have remained constant. Care was taken to measure exact values, for example the amount of water added to the food processor and the volume of sulphuric acid, potassium permanganate solution and nectarine filtrate added to each trial. The stopwatch would have caused the greatest amount of uncertainty in the method as it relied on the reaction time of the person conducting the experiment. While the observer was constant throughout all of the trials, a number of different factors could have affected how quickly the stopwatch was started/stopped and subsequently, the time that was recorded. In improving the method, the 'end-point' could be objectively tested for using colorimetric methods. A standard solution could be passed through the colorimeter and the time taken for the solution to reach a certain percentage of light absorption recorded. Each trial would be tested for in a similar way.

Ev: Considers uncertainties and their impact. However it is not so much the experimenter's reaction time as the ability to judge when the fading pink colour has disappeared that will influence the results.

Ev: Sensible realistic improvement

Potassium Permanganate, which was used as the indicator solution for this experiment, is a strong oxidising agent. With the ability to convert alkenes to glycols and thereby detect the presence of unsaturated bonds in a solution, the potassium permanganate could have reacted with impurities in the nectarine filtrate. In such a case, this would have affected the results considerably, as the time taken for the pink colour of the potassium permanganate solution to disappear might not have been just testing for glucose. Thus the person conducting the experiment was in reality testing for another variable, the metabolism of impurities in the filtrate, which had not been accounted for in the method. In order to reduce this error, another indicator solution, which does not react with impurities to the same extent as potassium permanganate, could be used, for example iodine solution. Deep blue in colour, iodine solution detects the presence of starch in biological samples. Recognising that starch hydrolyses into glucose molecules, iodine could be used to show the concentration of starch in the nectarine filtrate, diminishes with the ripeness of the fruit. Alternatively a specific glucose test such as that used by diabetics could be used.

Ev: an important source of error identified and its significance is assessed.

Ev: Logical suggested improvement. It will be specific to falling starch levels rather than rising glucose levels.

Ev: Could be an appropriate alternative (even if these tests are only usually semi-quantitative).

In the method, it was decided that each individual fruit should be tested three times, i.e. the time it took for the pink colour of potassium permanganate solution to disappear when placed with the filtrate was tested three times using a constant solution. Due to the subjective nature of the 'end-point' test, where we look for a change in colour to indicate the metabolism of carbohydrates to glucose, testing each solution three times limited any error that might be associated to the stirring of the solution and minimised the possibility of outliers in my results.

Ev: Discusses reliability

Each repeat was independent of one another, i.e. the nectarines from Day 3 and Day 5 trials had no relation to one another. A variety of different factors, which were not accounted for in this experiment and which could have been present in the repeats, for example the presence of pesticides and artificial ripening agents, or a former exposure to ethene gas, could have influenced the results. In effect, this meant that the method relied on commonalities between all of the nectarines in determining a relationship between the production of ethene gas and glucose concentration. The standard deviations remain reasonable except for the rice packaging treatment on Day 7. In general the standard deviation increased with the duration of the ripening. This might be expected as the fruits will vary at slightly different rates.

Ev: Considers reliability and its impact.

The abscission zone, or the region the closest to the stem of the fruit, has been shown to contain higher concentrations of glucose⁵. In order to minimise this factor, when pulverising the nectarines into a filtrate, the person conducting the experiment made use of all of the flesh of all the nectarines. This meant that the variation of glucose concentration within the fruit would remain constant throughout the experiment.

Ev: Considers accepted scientific theory but the discussion could have referred back to the context set in the introduction.

The biodegradation process, whereby microbes chemically digest materials, was one of the largest sources of error in this experiment. Mould, which develops as a result of an excess of moisture in an environment, was observed on all nectarines in the banana and rice trials after Day 5. The extent to which the propagation of mould had on the results can be seen in the calculated standard deviation values for the rice packaging trial. Day 7, in particular, had a massive standard deviation (16.18s), indicating that there was an enormous spread of data. Furthermore, because chance was a major factor in these results, they are not reliable and could probably not be reproduced again. The reproduction of microorganisms is affected by temperature. Therefore, the maintenance of a constant and relatively low (around 15°C) temperature would restrict the development of microorganism reproduction without significantly affecting the temperature required by the ripening process (remembering that the enzymes

Ev: Relative impact of uncertainty considered.

Ev: Evaluates the reliability of the data.

Ev: Feasible modification

⁵Studies on locating the signal for fruit abscission in the apple tree. J. Beruter and Ph. Droz, Swiss Federal Research Station for Fruit-Growing, Viticulture and Horticulture, CH-8820 Wädenswil Switzerland, Accepted 8 October 1990- Available online 14 October 2003

involved in the conversion of polysaccharides to monosaccharides work within a specific and narrow temperature range). The contamination of the fruit by microbes might be reduced by making sure the fruit is thoroughly cleaned on its surface before use. A sterilisation solution might be used.

Certain measures were taken to achieve environmental controls, for example temperature and exposure to light. The experiment was conducted in room temperature conditions, with the temperature of the laboratory being recorded twice each day. It was observed that the temperature fluctuated between 28°C and 29.5°C during the day. No recordings were taken between 3pm and 8am. There would have been great variation at night; however, this could not be controlled by the observer due to practical reasons, ideally, the experiment would be left in a consistently controlled environment, for example an incubator, where a constant temperature could be maintained.

Comm: These data could have been presented earlier.

Ev: Suggests realistic improvement.

The standard reference curve for glucose concentration that was produced proved to be irrelevant for the data. The data obtained was outside of the range of the standard curve. It was not possible to extrapolate the standard curve to cover the range of outcomes and therefore to infer the glucose concentration arising from the experimental trials. A calibration curve using higher concentrations of glucose would have to be reproduced.

Ev: Identifies weaknesses

Ev: Suggests realistic improvement.

Due to time constraints each trial was only repeated four times. In order to be able to draw concrete conclusions, 20 repeats would be required. This was taken into account when processing the results and it was acknowledged that any conclusions drawn from this experiment may or may not be wholly accurate.

Evaluation and Conclusion

It was hypothesised that the nectarines exposed to the rice-packaging trial would contain the highest concentration of glucose. It was thought that the rice would be conducive to the retention of ethane gas produced by the nectarines themselves around the fruit, hastening the ripening process and increasing the rate at which starch metabolised to glucose. In addition, the rice and nectarine were stored in a container from which air had not been removed. By contrast, the air had been removed from the plastic bags containing the fruit from the other two trials. It is possible that the higher concentration of oxygen in the box would have helped promote the metabolic process and the propagation of mould.

Comm: Another typo?

Bananas are used in both traditional and industrial situations to induce the ripening of fruit, due to their ethene-producing characteristics. This assertion, however, cannot be seen in the results. Whilst the bananas might have produced a small amount of ethene, on Day 7 of the experiment the control trial had a higher concentration of glucose though the results are not very different from the banana treatment though this difference is significant according to the t-test carried out on these data. The fact that the nectarines placed into plastic bags individually ripened at a faster rate than the nectarines that were placed with the bananas points to two possible conclusions. Firstly, methodological error meant that the conditions in which the bananas were placed were not conducive to the production of ethene. Or, secondly, that the nectarines used in the control trial were affected by factors that were not accounted for in this experiment, for example they contained higher concentrations of glucose at the beginning of the experiment.

Ev: Refers back to context

Ev: Identifies weakness but needs to suggest improvements.

It can be seen in Figure 1 that in all three of the trials the nectarines increased their glucose concentration at a similar rate from Day 1 to Day 3. We can thus assume that in this time period, the nectarines metabolised starch at a similar rate and produced similar amounts of ethene gas. It can be seen in the Qualitative Data Table that on Day 3 there were no definitive signs of mould, except on Nectarines 1 and 4 of the banana trial.

On Day 5 of the experiment, the banana and controlled trials continued to increase their glucose concentrations at a similar rate, albeit slower than the rate increase from Day 1 to Day 3. The rice packaging trial, however, had continued to increase its glucose concentration at the same rate, demonstrating a linear relationship between the concentration of glucose (y-axis) and time (x-axis). All of the nectarines subjected to these conditions were mouldy and were secreting a white residue. This was not the case with the nectarines in the banana and controlled trials, which showed little to no mould. One can deduce that it was the presence of mould that caused the sharp increase in glucose concentration. The enzymes from the mould are probably hydrolysing the starch of the nectarines.

An: Interpretation is sound and relevant

As the nectarines in the banana and controlled trials continued to increase their glucose concentrations from Day 5 to Day 7, the nectarines in the rice packaging trial began to decrease in glucose concentration. Probably consumed by the microbes. At the same time, it was observed that all of the nectarines in this trial had become increasingly mouldy - all were at least 90% covered in mould - and that all nectarines were secreting a white residue. One possible conclusion that can be drawn from this observation is that there exists a 'threshold' whereby the increasing glucose concentration is counteracted by the increasing development of mould colonies. As large starch molecules are metabolised there will be a rise in the concentration of glucose. This process develops parallel to the growth of mould and bacterial colonies, which will feed off the increasing concentration of simple sugars and 'spoil' the fruit. From the results obtained in this experiment, it can be seen that the glucose concentration corresponding to the 29.53 seconds it took for the pink colour of the potassium permanganate solution to disappear is the highest attainable concentration of glucose. After this, the amount of glucose consumed by the microbial colonies outnumbers the amount of glucose being produced by the hydrolysis of starch, and thus a decrease in glucose concentration can be observed. As seen in all three of the trials, the development of mould before this 'threshold' does not have a significant affect on the increasing glucose concentration.

Ev: Reasonable conclusion made

The only differentiating factor that could be observed in this experiment was the removal of air (oxygen) from the plastic bags. On Day 5, the controlled and banana trials possessed relatively similar glucose concentrations and in both of these trials, the air had been removed. Therefore it is unlikely that ethene gas produced by the banana was a significant factor in the conversion of starch to glucose. In the rice trial, where air was not removed from the box, the glucose concentration was significantly higher. The hypothesis that the presence of rice caused the ethene to be concentrated around the fruit does not hold up as ethene gas would equally have been retained around the fruit in the control trial. It is more likely that it was the presence of air, and oxygen in particular, that promoted both the growth of mould and the higher glucose concentration.

Ev: Implications considered

Ev: Valid conclusion

All of trials produced more or less the same outcome (the final values all lay within a 4 second period except Day 7 of the rice treatment). Qualitatively, all of the nectarines were observed as being rotten and covered in mould. The large standard deviations that were calculated from these results emphasised the wide spread of data around these three points and demonstrated the unreliability of the data on Day 7 of the rice treatment. The R^2 values remain high for the control and banana treatment remain high but the rice treatment R^2 is lower, reflecting the problems with these fruits.

As the nectarines were observed as being covered in mould and at this stage, it was likely that other significant chemical reactions were taking place within the fruits. The rice packaging trial had a standard deviation of 17.8 seconds, producing an error bar that encompassed all of the experimental results of the other trials (see Figure 1). The results of the experiment are in part due to processes that were not initially anticipated.

Comm: The candidate is getting a bit repetitive here.

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