ALL ABOUT THE BIOLOGY INTERNAL ASSESSMENT(IA)

- *Features of a high quality IA*
- *How to guide students through the process*
- *How to mark effectively for students and moderators*

Peter Marier, 2021

THE INTERNAL ASSESSMENT (IA)

- Enables students to demonstrate the application of their skills and knowledge, and to pursue their personal interests, without the time limitations and other constraints that are associated with written examinations
- The internal assessment should, as far as possible, be woven into normal classroom teaching and not be a separate activity conducted after a course has been taught
- Compulsory for both SL and HL students with identical criteria
- Criteria vary between different subject areas (like ESS and DT)
- Worth a significant portion of the course grade (20%) or even more if non-exam route

WHY DO I CARE SO HARD ABOUT IT?

As a biology teacher, my primary goal is for my students to enjoy and appreciate the study of science – if they end up pursuing a career in the field, BONUS!

Problem it is difficult for students to see learning science beyond exam preparation, i.e. ***"what do I need to know in order to regurgitate it later and then delete it"***

Solution personal agency in a project they care about

- An IA is a window into the scientific method and academia
- Bridges the gap between theory and application
- Students will poor exam skills can see success here
- More interaction with students can greatly improve relationship and engagement in the course
- Fosters student independence towards project completion

MAKING SENSE OF THE CRITERIA

- Levels of performance are described using multiple indicators per level.
- At a specific level, indicators can be all present, separated or all-together absent
  - ➢ a candidate can demonstrate performances that fit into different levels.

How to fix this???

Markbands are used and examiners and teachers use a best-fit approach in deciding the appropriate mark for a particular criterion.

Exploration

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 DP 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***.
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***.

* This indicator should only be applied when appropriate to the investigation. See exemplars in TSM.

WHERE TO GET INFORMATION

Teacher Support Material Links to all subjects in all offered languages has been compiled ***here***

- Visit the support material for your subject area
- Become familiar with the criteria
- Look through student assessed samples

EXPAND UPON VAGUE CRITERIA

- The IA markbands can at points be vague (in my opinion) and this makes it tricky to determine what markband a student's work is best deserving.
- Chris Pain at Bioknowledgy has created a fantastic expanded rubric * that can help in partitioning and determining what evidence constitutes what band.

Personal engagement

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	Aspect		
	Exploration	Personal significance	Intiative
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.

Checklist								
	P1.1	Arguments and discussion show intelligent use of citations, not reliance on them.		P2.1	RQ of question is based on prior research, but does not repeat it.		P3.1	Novel or innovative approach to address the research question	
	P1.2	Arguments consider data, published data and observations together, not as separate entities.		P2.2	RQ based on personal interests		P3.2	Method uses known protocols, but adapts them to the investigation with good reason.	
	P1.3	The discussion uses theory/citations beyond the research question to explain anomalies and trends, if necessary and relevant.		P2.3	RQ is relevant to local issues.				
				P2.4	RQ is novel and/or unusual.				
	n.b. Unlike other criteria personal engagement there just has to be point of evidence against an aspect, it does not have to comprehensively meet all mark points.								

** found in PD session folder*

FORMULATING RESEARCH QUESTIONS

A large hurdle for students is coming up with an idea for their IA

TIPS

- Personally relevant/interest
- Unique in some way (topic/method/analysis, etc.)
- Relevant/applicable to local +/ global issues
- Extends prior studies
- Students must be able to justify WHY they are choosing a topic and why it's important
- Student cannot repeat IA ideas from their other courses or have IA similar to their peers in the same class – each IA should be unique

***Rule of thumb** if you know what's going to happen it a bad/boring topic.*

FORMULATING RESEARCH QUESTIONS

- Depending on how many students you supervise, there could be a large requirement for unique ideas in a given year.
- Thus, I tell students, the earlier they can get an approved topic, the better as it will be off the table for others – i.e. first come first served for topic selection

→ ***I share a spreadsheet* with my class early which guides them in topic creation.***

Student Name Name Box	IV	Experimental Groups (with unit)	DV	Repeats/experimental group	Study Species	Controls	Location of data collection: lab or home	Personal Engagement	RQ	Approved/Declined	Teacher Comments
Sample 1 (Great)	ratio of SAP to soil	One control + five test groups (0:100, 0.5:100, 1:100, 1.5:100, 2:100, 2.5:100)	growth of bush bean measured as length (cm) and leaf count	5	*Phaseouls vulgaris* (bush bean)	- amount of water - Amount of soil - temperature	Home - will grow the plants myself over 4 weeks in the summer	Water stress in Qingdao, potential solution to farming in areas of drought Extending prior study on the topic: http://jcnqt.com/wp-content/uploads/2016/12/sap.pdf	How does the ratio of super absorbency polymer (SAP) to soil affect the growth of *Phaseouls vulgaris* (bush bean) under conditions of water stress?	Approved	controls - amount of water given to plants? what about the type of soil? temperature of what - air? soil? both?
Sample 2 (not so great)	Temperature	10, 20, 30, 40, 50	Enzymatic rate of reaction	3	no study species but the enzyme catalase		Lab - will need at least 3 lab sessions	Really interested in this topic - really cool!	How does temperature affect the rate of reaction of catalase?	Declined. Repeat of of a core practical with nothing new/extension	IV - temperature of what? units? Ex Groups - units? DV - how are you measureing this? repeats - 3 is insufficient, *at least* 5 RQ - too vague Personal engagement - this is taught in subtopic 2.5, not very novel...
Last, First											

** found in PD session folder*

RQ EXEMPLARS

How does the ratio of super absorbency polymer (SAP) to soil affect the growth of Phaseouls vulgaris (bush bean) under conditions of water stress?

- ***Local environmental connection :*** Qingdao experiences drought conditions regularly which negatively influences crops. Investigation aims to tackle this issue by testing various ratios of SAP within soil to improve the efficacy of water retention and therefore plant growth.
- ***Extending prior studies :*** SAP : soil ratios investigated here are different than those in the literature
- ***Novel setup :*** investigation simulates conditions of water stress by providing half of the recommended water to the plants in order to make investigation more applicable and relevant. Use of SAP is also novel

RQ EXEMPLARS

How does the growth of Pisum sativum compare when watered by washed rice water versus tap water and NPK fertilizer?

- ***Cultural connection :*** student is Korean and wanted to test the cultural practice of using washed rice water to grow plants vs commercially available fertilizer to scientifically test this practice
- ***Environmental connection :*** Investigation is linked to reducing water consumption
- ***Novelty :*** Limited prior work done in this area
- Even though the experiment is rather plain (growth of plants), the blending of cultural practice demonstrates curiosity and novelty

RQ EXEMPLARS

To what extent does pretreating Pisum sativum L. seeds with gibberellic acid (GA3) improve germination success after 96 hours at different concentrations of NaCl (0.06M, 0.12M, 0.18M, 0.24M, 0.30M)?

- ***Personal environmental connection :*** Zeeland, NL (where student is from) experiences high salinity conditions which are worsening, impacting plant growth. Investigation aims to test the impact of a growth hormone on varying salinity levels by measuring germination success of a local salt-tolerant plant
- ***Extending prior studies :*** GA3 hormone not studied with this study species and limited studies examining impact at different salinity levels
- ***Complex methodology :*** investigation had two groups (hormone/no hormone), each containing 5 IVs

RQ EXEMPLARS

How does the amount of magnesium carbonate ($MgCO_3$) powder applied onto Raphanus sativus (radish sprouts) affect its growth as measured by change in plant length and mass after 10 days?

- ***Personal environmental connection :*** student is a rock climber which uses $MgCO_3$ as a powder. Curious if the deposition of this powder impacts local flora (study species)
- ***Extending prior studies :*** $MgCO_3$ was used but not on study species and applied as a solution, not powder.
- ***Unique investigation :*** investigation applies the powder in a unique student-developed manner which attempts to simulate deposition from rock climbing

RQ EXEMPLARS

To what extent can the concentration of capsaicin in gochugaru (Capsicum annuum) delay the time it takes for kimchi to reach its optimal pH of 4.5 during fermentation?

- ***Personal environmental connection :*** student is part Korean and his family makes kimchi at home. Wanted to test the practice of adding peppers in order to improve kimchi production. Used scientific methods to determine successful fermentation
- ***Unique investigation :*** investigation blends cultural practices and scientific theory. DV is the time it takes to reach a previously determined optimal pH. Method very much devised by student.

RQ EXEMPLARS

How does varying directional wind speed (0.0, 1.0, 2.5, 3.2 ms^{-1}) impact transpiration rate (µL/min) in Ficus umbellata differently for various leaf surface areas (small, medium, large) as measured by rate of water uptake using a potometer?

- ***Extending prior studies :*** prior studies examining impact of boundary layer due to leaf size is expanded upon using a living study species rather than model.
- ***Complex methodology :*** multiple IVs groups are examined simultaneously
- Even though the experiment is studied in AHL (potometers) the investigation is complex and examines factors beyond the scope of the curriculum

GUIDING STUDENTS

Go over the criteria, strand-by-strand

- What does it mean?
- How can this be achieved?
- Example of what this looks like

* Criteria can appear to be vague and difficult to understand, thus teachers have took it upon themselves to create more tailored guides/checklists to help students in determining whether they have met all the requirements.

→ Look online for these or create them yourself

How to read this guide

Bold Headers: refer to suggested sections included in the IA (these are given in the order they would appear in the written report)

- Clarifying points for elements of what should be included in these sections
- **[Codes]** reference the extended marking rubric by Chris Pain found here to justify why these elements should be included

* *Additional notes,* sometimes with examples from past student IAs

Title Page (optional)

- Research Question (RQ) as title
- Personal Code
- Page count (does not include title page or works cited, numbering should start on next page)

Background

- Provide context for your RQ (disturbance, climate change, infections, treatment, etc.) **[E2.2]**
- The reader should understand *why* you are doing this study, why it's important – it should clearly convey personal interest and try to include local issues (if possible) **[P2.2]** + **[P2.3]**
- Explain any scientific theory/information relevant to your study of which the reader should be made aware. **[E2.4]**
- Explain and justify your *study species* – why is this species being used? Could include picture of species to give more context

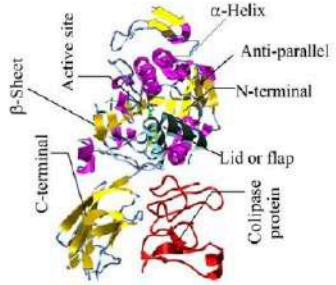


Figure 1 Structure of human pancreatic lipase (HPL) *(Mukherjee, 2014)*

* *When pictures are used, include a picture caption. If you didn't take the picture, reference its use* ***[C4.10]***

- Describe prior studies (if relevant) that have conducted a similar experiment and outline their findings **[E2.1]**

* *Search https://scholar.google.com/ using your chosen topic/variables to find and read relevant studies*

- Why is your study novel/different than past investigations? **[P2.1]** + **[P3.1]** If your study has already been done, explain what new aspect your investigation is bringing to the literature/topic **[P2.4]**

* *Entire section should be heavily supported with multiple, different, relevant scientific citations (scientific papers) and cited in a consistent format in-text (scientific, MLA, Oxford, etc.)* ***[E2.5] + [C1.6]***

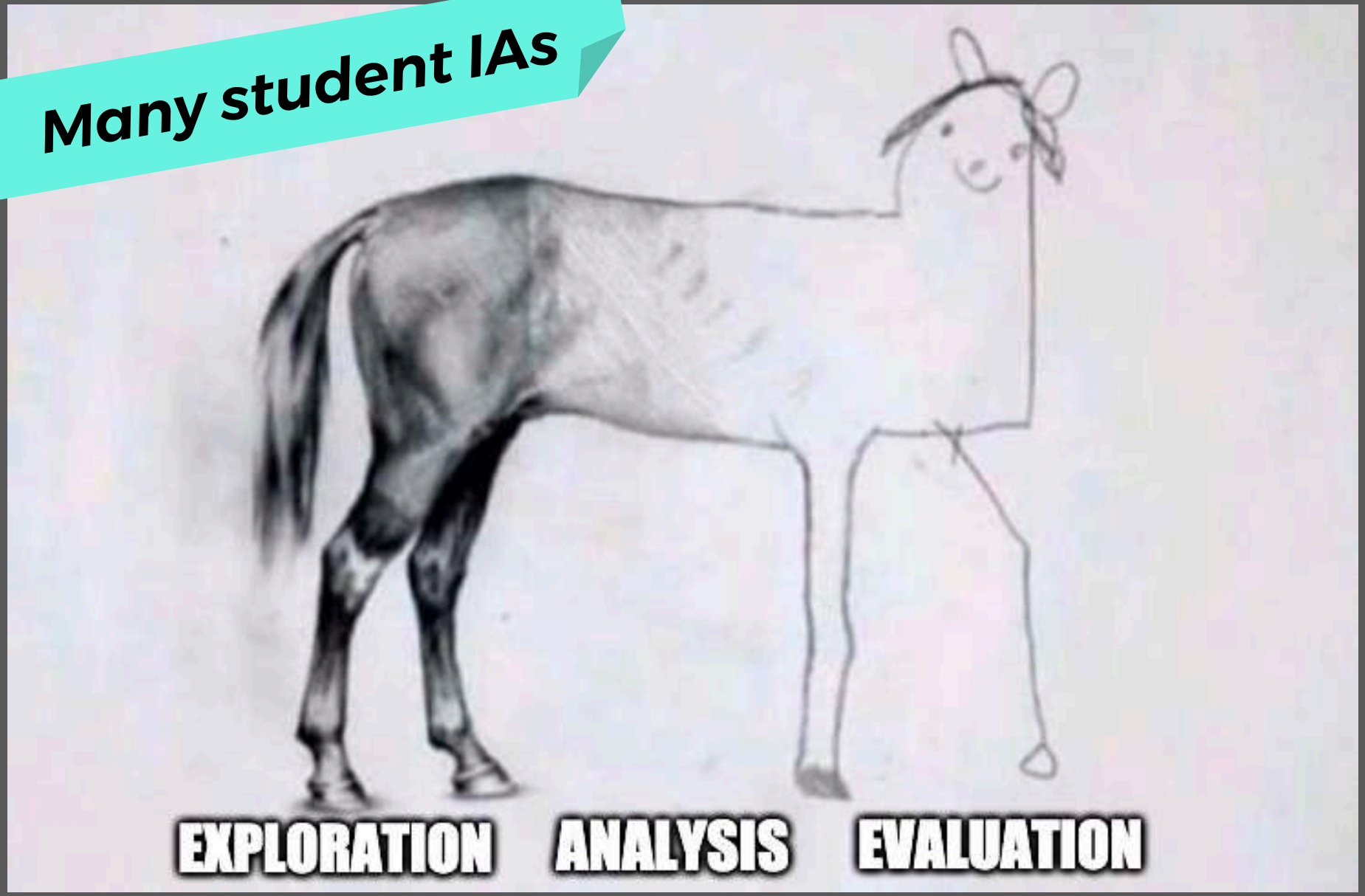
* *Citations should only be of information relevant to answering your RQ or its context* ***[C3.3]***

Aim of Investigation

- Provide a brief explanation of what you are going to do in your investigation, i.e. what is your goal?

* found in my resources folder

Many student IAs



BACKGROUND

- ***Organized***
  - →Headers/sub-headers + paragraphs
- ***Detailed***
  - →Personal engagement/novelty/prior studies
  - →Biological theory
  - →Study species
- ***Well-supported***
  - →Scientific sources (journals)
  - →Multiple sources

Personal Engagement **Exploration**

Background

Effect of salinity on germination

Seed germination is the resumption of growth of the embryo following a period of dormancy. Germination involves a series of metabolic processes that oxidize the lipids and carbohydrates stored within the seed cotyledon and break down storage proteins in order to obtain the energy and amino acids necessary for plant development. (Ali & Elozeiri, 2017) Seed germination begins with imbibition (uptake of water) by the dry seed and ends with radicle penetration through the testa, the protective layer that coats the seed. (Tuan et al., 2018) Saline conditions may prevent water uptake by the seed due to the reduction of external osmotic potential. (Berhanu & Berhane, 2014) As a result of the high solute concentration in the saline soil surrounding the seed, the water potential outside the seed is no longer significantly greater than the water potential inside the seed, thus reducing the net passive movement of water into the seed. Considering that water is needed for the metabolic activity in seed germination, the reduced water uptake inhibits germination. Moreover, high salt concentration may also inhibit seed germination due to the toxic effects caused by the uptake of ions contained in salts, such as Na^+ions and Cl^-ions. (Pereira et al., 2020)

Study species

Pisum sativum L. (the pea) is a cool season legume grown in many parts of the world in winter to early summer depending on the location. (Naz et al., 2014) *Pisum sativum L.* is one of the most tolerant legumes to salt stress. In a prior study, the crop yield of *Pisum sativum L.* was only reduced by 50% at 0.1M NaCl, a relatively high NaCl concentration. Meanwhile, other legume species studied suffered greater yield reductions, often at 80% or higher. (Ghezal et al., 2016) Nonetheless, the productivity of *Pisum sativum L.* is still markedly reduced at elevated levels of salt stress. In the Netherlands, the *Pisum sativum L.* is a popular winter food incorporated into many typical Dutch dishes such as "erwtensoep" (split pea soup). Although *Pisum sativum L.* is often imported from France and Belgium, the legume is one of the main crops grown in Zeeland, a province in the southwest of the Netherlands. ("Doperwt verliest terrein op Nederlandse akkers," 2017)

Salinity in Zeeland

Zeeland's farming fields are primarily located on areas of reclaimed land called the "polder" regions. The clay soil in these regions is highly saline, especially when compared to the rest of the Netherlands. This increased salinity is caused by the old seawater that became trapped in the groundwater when the polder regions were created. Despite the saline conditions, there are many farms in Zeeland due to the uniquely fertile conditions of clay soils. To deal with the saline conditions, farmers have opted for crops with moderate to high salt tolerance, including *Pisum sativum L.*, as well as a variety of other salt-tolerant crops, such as grasses, grains, and beets. (Boone, 2018) However, the sustainability of agricultural practices in Zeeland is under threat due to the gradual, but continuous, rise in salinity of Zeeland's soils. Currently, permanent groundwater drainage is keeping the polder regions sustainable; however, this on-going draining has also resulted in the mobilization of deeper and more saline groundwater, leading to increased salinization of soils and shallow ground water over time.(Oude Essink, 2011) Moreover, most of Zeeland lies below sea level; as a result, rising sea levels are also contributing to the increasing salinity of Zeeland's soils. (Stafleu et al., 2010) To ensure the continued viability of farming in Zeeland and to protect the livelihoods of Zeeland's farmers, it is important to find methods to effectively mitigate the negative effects of salinity on crop yield.

Pretreating seeds with GA3

One possible method of increasing agricultural yield in saline conditions is pretreating seeds with gibberellic acid (GA3) to overcome seed dormancy and thus reduce the inhibition of seed germination in saline conditions. Germination is under strict regulation of several plant hormones including GA3 and abscisic acid (ABA). ABA plays a key role in the induction and maintenance of seed dormancy while GA3 stimulates germination. (Tuan et al., 2018) ABA restricts embryo growth potential by inhibiting imbibition and hence cell-wall loosening, which is a key step to starting germination. (Vishal & Kumar, 2018) GA3, on the other hand, exerts its influence by activating specific genes for α-amylase mRNA transcription. Amylase facilitates starch degradation in the cotyledons and makes monosaccharides available to the newly germinating embryo. GA3 is also able to induce a range of other genes that are necessary for the production of enzymes that have a vital role in the germination process, such as lipases which are important in the early growth and development of seeds. (Nawaz et al., 2013) Moreover, GA3 triggers the weakening of the testa, thus allowing the radicle and plumule to protrude from the seed. (Gupta & Chakrabarty, 2013) Unfavorable conditions, such as saline conditions, lead to high ABA and low GA3 levels in seeds whereas favorable conditions cause the reverse situation.(Vishal & Kumar, 2018) By pretreating seeds with GA3, the GA3 levels inside the seed become greater than the ABA levels, thus increasing the chances that the seeds will break dormancy and germinate, in spite of the unfavourable saline conditions.

AIM, RQ, HYPOTHESIS

- Aim clearly provided
- RQ clearly stated
- Hypothesis provided clearly and justified using scientific theory

Personal Engagement **Exploration**

Aim of Investigation

To observe the degree of effect of wind speed on different size plants and to test if larger leafs have higher transpiration rate than smaller leafs at higher wind speeds.

Research Question

How does varying directional wind speed (0.0, 1.0, 2.5, 3.2 m s^{-1}) impact transpiration rate (µL/min) in *Ficus umbellata* differently for various leaf surface areas (small, medium, large) as measured by rate of water uptake using a potometer?

Hypothesis

Transpiration rate will increase with wind speed inversely exponentially, but plants with greater leaf SA will have greater effect from the increase in wind speed (trend represented on Figure 2). The relationship between wind speed and transpiration rate is since stronger wind speed pushes away more boundary layer but as wind speed increases, there would be less boundary layer to push away, decreasing the effect of wind speed. At higher wind speeds (over 3.0 m s^{-1} according to Figure 1), the increase in transpiration rate will start to settle as all the boundary layers is pushed away, but it shouldn't converge to a constant for this experiment since wind speed generally increase rate of evaporation whether or not there is a boundary layer (Bolton, 2019). Meaning there would be a direct relationship between rate of transpiration and wind speed at high wind speeds. The settling or the overlap in lines may begin at lower wind speed than 3.0 m s^{-1} due to that relationship. The rate of transpiration or the rate of water uptake (hereinafter "R_u") without wind would be greater for smaller leaves than larger, but the effect of wind speed will be greater on larger leaves with thicker boundary layer, so the transpiration rate of all three leaf sizes could be similar at higher wind speeds (greater than 3.0 m s^{-1}) or in fact higher for plants with larger leaf size since evaporation generally increases with surface area (McJannet et al, 2008). In Figure 2, with values of y-axis omitted since the specific value for rate of transpiration of *Ficus umbellata* was unclear before the experiment was conducted.

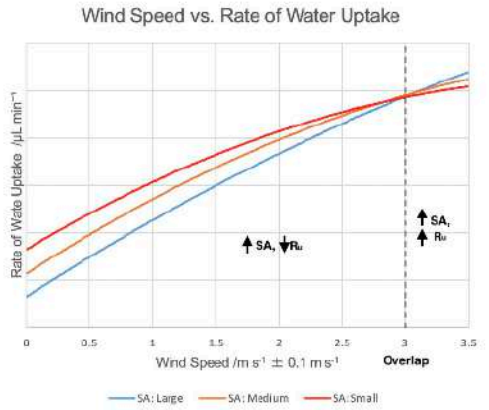


Figure 2: Graphical representation of my hypothesis, portrating wind speed against rate of water uptake with different leaf sizes

IV AND DV

- IV clearly stated along with the experimental groups
- Justification for why these groups were chosen (using scientific theory/past studies)
- DV clearly stated along with units
- Justification for why this method of measure is chosen + length of time (if applicable) using scientific theory/past studies

Exploration

Independent Variable - solutions apples were immersed in

Experimental groups - 10% solutions of 100% pineapple juice, 100% lemon juice, salt, honey, and distilled water as a control.

The solutes to be diluted in distilled water were chosen by comparing materials generally found in Japanese households to previous studies (Cindy B. S. Tong & Kevin B. Hicks. 1991), (Kim et al. 2004), (Lee et al. 2002), (Min-Kyung Lee. 2007), (Lim, W. Y., & Wong, C. W. 2018). Pineapple juice, honey, and salt were chosen per the study done by Lim and Wong where they used chili pepper extracts, onion extracts, pineapple extracts, and other materials that are not too common in households at least in Japan. The pineapple extract was substituted with 100% pineapple juice. Honey and salt was adopted from the study because of their abundance in households. Lemon juice was chosen because the studies mentioned previously used ascorbic acid on other fruits and vegetables. Ascorbic acid isn't found normally in common households but lemons and limes are known to be rich with ascorbic acid (C. Rekha et al. 2012) justifying their use in this experiment. The solution concentration of 10% was chosen based on the same study by Lim and Wong where they used solutions of 10mg/mL and ranges of concentrations for honey. A slight adjustment was made to fit my experiment in the case of honey by increasing the solution concentration of honey to 10% to keep a constant concentration among all experimental groups. Also, distilled water was used to act as a control.

Dependent Variable - the extent of browning

Method of measurement - Percent change in L*a*b* (lightness, redness, yellowness) and RGB (red, green, blue) values after 48 hours and 96 hours of immersion in solutions.

*Why L*a*b* and RGB values and how they will be measured*

RGB values each (R, G, B) ranging from 0 to 255, indicate the level of red, green, and blue. Therefore, changes in RGB values can be used to quantify the amount of change in color. However, the change in color cannot be used to determine which pigment is “more brown” as this is to individual human perception. Thus, RGB values will be used to quantify the amount of total color change. For L*a*b* values, numerous previous studies showed that the browning of fruit is correlated with an increase in the a* value (Rana et al. 2018). Therefore, although all L*a*b* values, L* indicating the lightness, a* indicating redness, and b* indicating yellowness will be recorded, the increase in a* value will be used to quantify the amount of browning within the experiment. Both the RGB and a* values will be measured as percentage change to easily understand the results. Both of these values will be collected by first, taking a picture of each apple slice using a DSLR. Next, these pictures will be processed through a background removing software (remove.bg), and finally into an image analysis software (Image Color Summarizer). The photos themselves will be taken under a controlled environment, provided by a cardboard photo booth made beforehand to ensure control over possible variables.

Determining the length of immersion, and time left out for browning to occur

Since none of the previous studies referred to went into detail about their procedure regarding the length of immersion or time left out after immersion, a preliminary trial was carried out by dipping a slice of apple into distilled water for a minute, then seeing how long it would take to brown. The preliminary trial showed that after 1 minute of immersion, it took 48 hours for it to exhibit significant browning perceptible to the human eye. Therefore, the length of immersion was set at 1 minute, and the time left out will be 48 hours and 96 hours. The 96 hours was added so that a short term-long term comparison could be possible.

CONTROLS

- Presented as a table (does not span pages)
- Impact of variable (why is this being controlled) justified using scientific theory

  → Should clearly relate to the DV
- Method of control (how is this being controlled) explained using specific apparatus and values

Exploration

Control variables

Variable	Impact	Method of Control
Concentration of GA3 used in pretreatment	The concentration of GA3 will determine how much GA3 can be absorbed by the seeds. A lower concentration would mean less absorbance of GA3, therefore limiting the extent to which the growth promotion of GA3 can overcome the dormancy promotion by ABA. At the same time, however, a high concentration of GA3 could also inhibit growth as a result of extensive premature weakening of the testa. (Gupta & Chakrabarty, 2013)	All seeds in the pretreated batch were pretreated in 200 mg/L GA3. Before experimentation, a standard solution of 200 mg/L GA3 was prepared. (see part 2: pretreating seeds with GA3) This concentration was chosen at it has been used in a prior study which studied the effects of GA3 pretreatment on the germination of legumes other than *Pisum sativum L.* and found 200 mg/L to be the GA3 concentration resulting in the highest FGP. (Tsegay & Andargie, 2018)
Duration of GA3 pretreatment	If seeds are pretreated by GA3 for a longer period of time, the seeds will have absorbed more GA3. This increased uptake of GA3 will enhance the germination stimulation caused by the GA3. Similarly to concentration of GA3, however, if the seeds are soaked in GA3 for too long, the seeds will absorb too much GA3 thus inhibiting germination and reducing the positive effects of GA3 treatment.	All seeds in the pretreated batches were soaked in 200 mg/L GA3 for 24 hours. This duration was chosen based on prior studies that investigated the effects of pretreating seeds with GA3. (González-López & Casquero, 2014) (Tsegay & Andargie, 2018) Any pretreatments of longer duration, such as 48 hours, were shown to reduce germination success. To control the pretreatment time, as soon as the seeds were placed in the GA3 solution, a 24-hour timer was started using a stopwatch. Once 24 hours had passed, the seeds were removed from the GA3 solution and rinsed with distilled water to remove any GA3 left on the exterior of the seeds. Then, prior to beginning the germination study, the seeds were gently dried with paper towels.
Number of *Pisum sativum L.* seeds per filter paper	When there are a greater number of seeds per filter paper, the volume of saltwater contained in the filter paper is shared amongst a greater number of water-absorbing seeds. As a result, the number of Na^+ and Cl^- ions absorbed by each seed is less. This would affect germination success considering that there would be a decrease in the toxic effects of the absorption of Na^+ and Cl^- ions. (Pereira et al., 2020) Moreover, a greater number of seeds per filter paper would also determine how much water is available for imbibition per seed, thus influencing imbibition and consequently germination success.	25 seeds were placed in between each pair of filter papers. This number was decided by testing how many *Pisum sativum L.* seeds could fit on a filter paper without reducing the ability of another piece of filter paper to be securely placed on top.
Volume of saltwater applied to filter papers	A greater volume of saltwater would have two effects on the germination of seeds that are similar to the effects of 'number of seeds per filter paper'. Firstly, there would be a greater number of moles of NaCl available for absorption by the seeds. The potential increase in uptake of Na^+ and Cl^- ions would enhance the toxic effects of these ions, thus inhibiting germination success. Secondly, there would a be a greater volume of water available for imbibition, potentially increasing germination success.	Prior to experimentation, saltwater was applied to filter papers with a spray bottle. Each filter paper was re-dampened after 24 hours, after 48 hours, and after 72 hours. To control the volume of saltwater being applied to the filter papers, 5 sprays were consistently used to dampen each filter paper. While doing so, the nozzle setting of the spray bottle was kept constant as this controlled the amount of saltwater coming out of the bottle with each spray. The spray bottle used had three settings ranging in different volumes of saltwater being sprayed. For each application of saltwater, the 'medium' nozzle setting was used.
Temperature during germination	Temperature affects germination in three ways. Firstly, for seeds to germinate, they need to imbibe water. For this to occur, sufficient amounts of water must be contained in the filter paper. A higher temperature may increase evaporation and decrease filter paper moisture, which would negatively affect germination. Secondly, germination is a metabolic pathway that is regulated by a variety of enzymes involved in catalyzing the production of hormones as well as the breakdown of lipids and carbohydrates as energy sources. The closer the temperature is to the optimal temperature of the enzymes, the greater the germination success. Lastly, temperature can increase the transcription of genes that control the production of gibberellins, thereby affecting germination success. (Stolárik et al., 2015)	The seed batches were germinated in a fume hood considering that this is a dark, enclosed space. During the preliminary trials, a thermometer was used to check the temperature in the fume hood every 24 hours. The temperature was found to remain constant in the range of 22°C - 23°C. A prior study had found that the optimum temperature range for the germination of *Pisum sativum L.* seeds is 20°C to 26°C. (Dove, 2010) Considering that the temperature conditions within the fume hood corresponded with the optimal temperature range for the germination of *Pisum sativum L.* seeds, no additional precautions were taken to control the temperature. To reduce the impact of any minor fluctuations in temperature, the pretreated and untreated seed batches for all experimental groups were studied at the same time. This way, if there were any temperature fluctuations, all seeds studied would be subject to the same temperature fluctuations.
Light during germination	The results of a prior study show that *Pisum sativum L.* seeds germinate the fastest in dark conditions. (Erdei et al., 2005) If the *Pisum sativum L.* seeds are subject to lighter conditions, their rate of germination would decrease and the seeds may even remain in dormancy, thus affecting germination success.	*Pisum sativum L.* seeds were germinated in a fume hood which is a dark and enclosed space. Moreover, to prevent any light from shining into the fume hood, the fume hood was covered with large sheets of opaque black paper.
Time given to germinate	The time given to germinate will determine the number of seeds that germinate during the duration of this investigation, thus influencing the FGP that is calculated after data collection.	Preliminary trials were conducted to determine the germination time of untreated *Pisum sativum L.* seeds in non-saline conditions. 75 seeds were left to germinate in the fume hood. After 96 hours, 90.7% of seeds had germinated. Thus, it was determined that seeds would be given 96 hours to germinate. At the start of experimentation, a stopwatch was started and after 96 hours, the number of germinated seeds was counted.

RISK MANAGEMENT

- Regardless of the dangers within an investigation, this section NEEDS to be present and detailed
- Risks should be clearly identified and explained along with detailed methods of preventing harm
- Some experiments may have no health risks and this should be mentioned. However ***all*** investigations need to consider ethical/environmental concerning regarding waste and disposal

Exploration

Risk Management

Hazard	Nature of Hazard	Control
Molds growing on the surface of milk and container caps, namely *Penicillium* and *Aspergillus* after having been spoiled.	Many species of *Penicillium* produce highly toxic mycotoxins. *(A.A. El-banna, J.I. Pitt, L. Leistner. 1987)* Breathing in *Aspergillus* spores can cause an infection in the lungs or sinuses. *(US Department of Health & Human Services. CDC. 2020)*	Container caps with mold should only be held by the rim. Regardless of the presence of molds, the surface of milk should not be touched at all times. Disposable gloves and a facemask will be worn when handling the containers. If the molds come into contact with skin, they will have to be washed off immediately with soap.

Environmental Considerations

Since the milk needs to be disposed of after the experiment as it will likely be unsuitable for consumption, only 30 mL of milk will be poured into each container so as to minimize the waste while ensuring that it is not too little for pH measurement using a pH meter. According to The Department of Primary Industries and Regional Development of Western Australia, milk has a biological oxygen demand (BOD) of 30,000 mg/ L. If a watercourse is contaminated with pollutants with high BOD, so much oxygen is consumed by microbes that oxygen levels become too low to support aquatic life and result in deaths. *(Agric.WA.gov. 2018)* Instead of pouring it down the drain, the milk was diluted with distilled water and given to garden plants for calcium.

Risk management

Hazard	Nature of the hazard	Control
NaCl solution, especially the handling of NaCl during the preparation of the NaCl solutions	Can cause skin/eye irritation upon contact	Wearing goggles and latex gloves. Additionally, NaCl solutions were stored in sealed volumetric flasks with clear labels
GA3 solution	Can cause skin/eye irritation upon contact	Wearing goggles and latex gloves. Additionally, GA3 solution was stored in sealed volumetric flasks with clear labels

Ethical/environmental considerations

The method used was relatively safe. The only hazard to the individuals conducting the experiment was the preparation and handling of the NaCl solutions and the GA3 solution considering that both NaCl and GA3 are body tissue irritants, especially to the eyes. (PubChem Database, n.d.) This potential hazard, however, was controlled through the use of protective equipment, as outlined in the risk management table. At high volumes, GA3 solution and NaCl solution are both also potential hazards to the environment, as a result, ensuring the safe disposal of these solutions was important to preventing any environmental harm. (PubChem Database, n.d.) Both the NaCl solution and the GA3 solution were therefore carefully disposed of using a waste liquid recovery tank. The ethical disposal of the GA3 pretreated seeds also had to be considered in order to prevent unnecessary wastage of seeds. It is possible to plant GA3 pretreated and untreated seeds after their use in a scientific investigation. (ASTA, 2014) Planting the seeds, however, was not a viable option in this investigation due to the lack of available soil for planting in the vicinity and the lack of time to ensure proper care. Instead, the seeds were composted.

MATERIALS

- Can either provide all materials for the experiment at the start of the methodology (top example) or provided before each section of the methodology (bottom example)
- Measuring apparatus should include uncertainties
- Chemicals/substances should include quantities
- Containers should include dimensions/volume

Exploration

Materials/Apparatus:

- 1 medium sized head of napa cabbage (~1kg)
- ¼ cup of coarse sea salt
- 1 tablespoon of minced garlic
- 1 teaspoon of minced ginger
- 2 tablespoons of fish sauce (Chung Jung One brand)
- 1 Vernier LabPro pH sensor (±0.01 pH) (with appropriate cables)
- 1 teaspoon of brown sugar
- 30 IKEA brand sandwich bags (16.5cm x 14.9cm)
- 7½ cups of gochugaru
- 1 Sharpie marker
- Paper towels
- 8L of tap water
- 6 pairs of disposable rubber gloves
- 1 small metal spoon
- 6 small mixing bowls (~10cm in diameter)
- 1 measuring cup (±2.5ml)
- 1 measuring spoon (±0.5ml)
- 1 electronic scale (±0.5g)
- 1 large mixing bowl (~35cm in diameter)
- 1 electronic timer (±0.01 seconds)
- 1 pair of protective glasses
- 1 electronic thermometer (±0.5°C)
- 1 kitchen knife
- 1 cutting board
- 1 2L measuring jug (±25ml)
- 1 strainer
- 1 insulated icebox (~40cm x 40cm)
- 1 computer (with LoggerPro3 installed)

Unit Conversion (±0.5ml):

1 tablespoon = 15.0ml
1 teaspoon = 5.0ml
1 cup = 236.5ml

Materials, Apparatus & Method

Part 1: Preparing NaCl solutions (saltwater solutions)

- 1 x electronic balance (±0.0005g)
- 13.2 g NaCl
- 1 x weighing boat
- 1 x funnel
- 1 x 250mL beaker (±12.5mL)
- 1250 mL distilled water
- 5 x 250 mL volumetric flask (±0.015mL)
- 1 x glass rod

1) Use the electronic balance and the weighing boat to measure 0.877g of NaCl
2) Pour approximately 200mL distilled water into the 250mL beaker
3) Put the 0.877g of NaCl from step 1 into the 250mL beaker with distilled water
4) Use the glass stirring rod to stir the distilled water and NaCl until the NaCl has completely dissolved
5) Using the funnel, pour the dissolved NaCl solution into a 250mL volumetric flask
6) Top off the volumetric flask with distilled water until the bottom of the meniscus reaches the 250mL mark
7) Shake the volumetric flask for 15 seconds while securing the lid with your thumb
8) Seal the volumetric flask with its lid and label the volumetric flask as "0.06M NaCl solution"
9) Repeat steps 1-8 four more times to create 250mL of 0.12M, 0.18M, 0.24M, and 0.30M NaCl solution. Based on the concentration of NaCl being prepared in each repeat, adjust the mass of NaCl being used and change the label being put on the volumetric flask. See table 1 for the masses of NaCl needed to prepare each concentration of NaCl solution.

Table 1: Masses of NaCl needed to prepare 250mL of different concentrations of NaCl solution

Concentration of NaCl solution (M)	Mass of NaCl (g) (±0.0005g)
0.06	0.877
0.12	1.753
0.18	2.630
0.24	3.506
0.30	4.383

METHODOLOGY

- Should be specific with apparatus, volumes, quantities, etc.
- Rule of thumb: if it's not written, it is not done. Need to be very explicit

Bad Ex pour water into graduated cylinder

Good Ex pour 40mL water into a 50mL graduated cylinder ± 0.5mL

- Should include diagrams or experimental setup for clarity
- If methodology is adapted from a known protocol, should be referenced

Personal Engagement **Exploration**

Preparing spices for different test groups:

1) Put on the protective glasses. Then, using the measuring spoon (±0.5ml), measure out ⅛ teaspoon of brown sugar, ⅛ tablespoon of minced garlic, ⅛ teaspoon of minced ginger, and ⅓ tablespoon of fish sauce and add them to one of the six small mixing bowls. Repeat this for the remaining five bowls.
2) Using the measuring cup (±2.5ml), measure out ½ tablespoons of gochugaru and add it to one of the small mixing bowls. Increase the measurement of gochugaru by ½ of a tablespoon and add it to the remaining bowls until 2½ tablespoons of gochugaru is added to one of the small mixing bowls. Ensure that one of the small mixing bowls containing only the controlled ingredients does not contain any gochugaru.
3) Using a small metal spoon, stir the ingredients until it becomes a smooth paste. Make sure to rinse the spoon after stirring one bowl and before moving on to stir another to avoid cross-contamination.

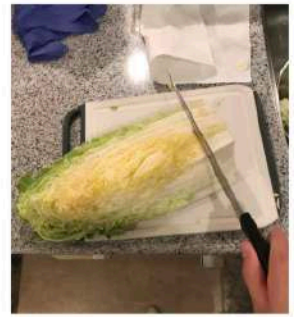


Figure 1: Quartering and slicing the cabbage

Preparing kimchi batches:

1) Place the cabbage on the cutting board and use the knife to cut it lengthwise, before cutting out the cores at the stem and finally cutting the halves lengthwise once again to produce 4 quarters. Cut across the quarters to create bite-sized pieces, leaving around 5 cm between each cut (as seen in Figure 1).
2) Place the cabbage pieces into the large mixing bowl and using the measuring cup (±2.5ml), measure out ¼ cup of coarse sea salt and add it to the large mixing bowl. Put on a pair of gloves and massage the cabbage until it starts to wilt. Using the measuring jug (±25ml), measure out 1.5L of tap water into the bowl and add it to the bowl until it just covers the cabbage pieces.
3) Prepare an environment of 25.5°C by leaving the icebox open in an environment at that temperature (as determined by the use of an electronic thermometer (±0.5°C)) for 30 minutes (measured by the electronic timer (±0.01 seconds)).
4) Place the large plate over the bowl to cover it and leave it inside the icebox and close it before setting the electronic timer (±0.01 seconds) for two hours.
5) After waiting the two hours, pour the cabbage into a strainer and let it sit for ten minutes before placing it back into the large mixing bowl. Measure the mass of the cabbage using the scale (±0.5 g) (making sure to exclude the weight of the bowl) and divide the mass into six equal portions.
6) Place each portion of cabbage into one of the six bowls containing the spice pastes. Using gloves, gently work the paste into the cabbage until it is thoroughly coated (as seen in Figure 2). Make sure to use different rubber gloves for each portion to ensure cross contamination does not occur.

Figure 2: Combining the cabbage and spice paste

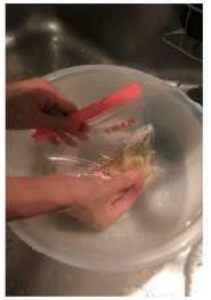


Figure 3: Vacuum sealing the IKEA bags

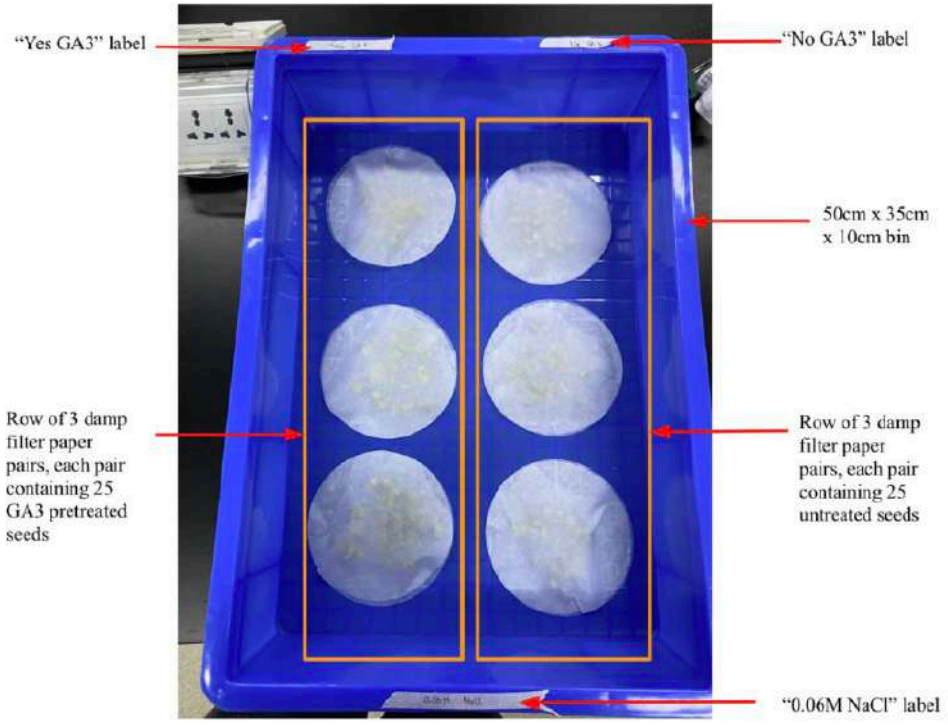


Figure 4: Final set-up of 75 untreated *Pisum sativum L.* seeds and 75 GA3 pretreated *Pisum sativum L.* seeds in 0.06M NaCl solution

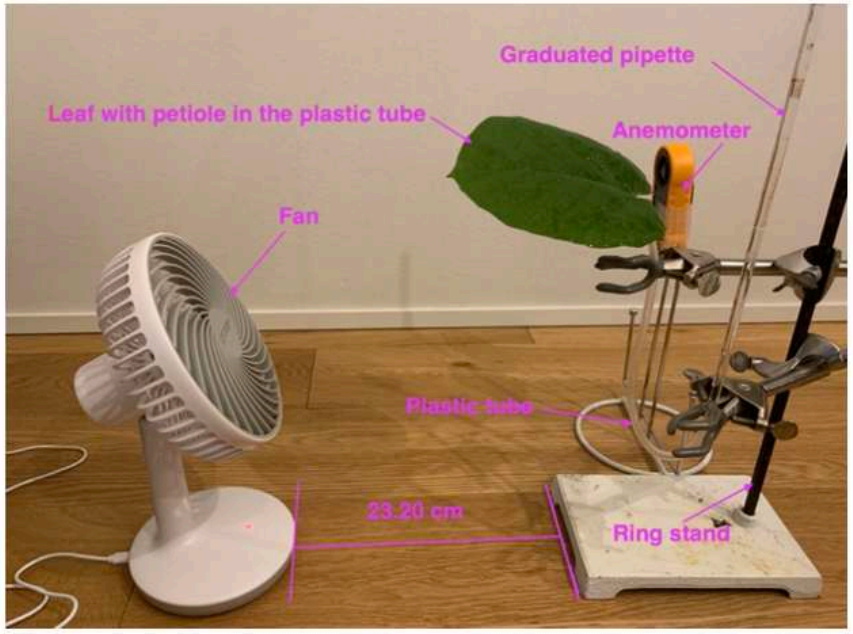
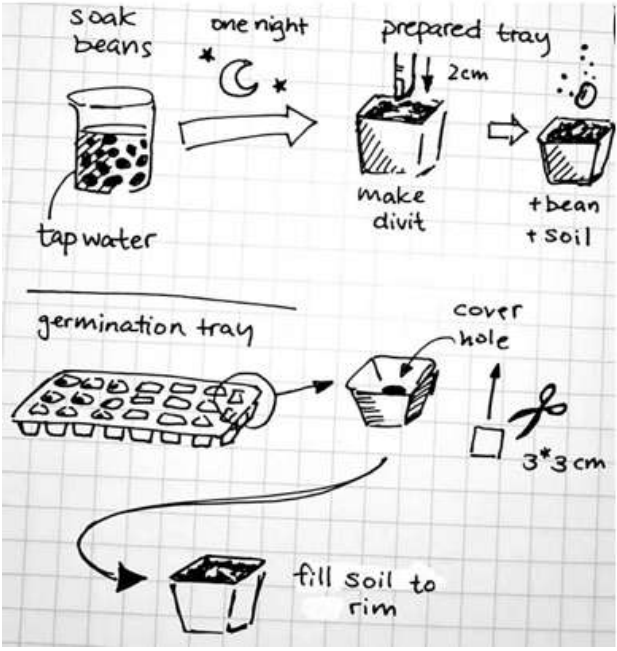


Figure 3: The experiment set up during data collection.

Figure 4 Preparation of seedlings



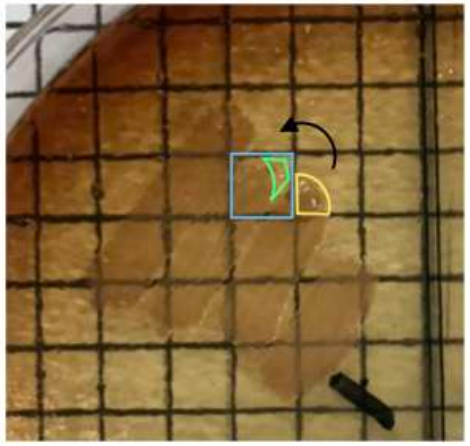


Figure 9. example of how to organize and count number of bacteria filled squares

Fig. E

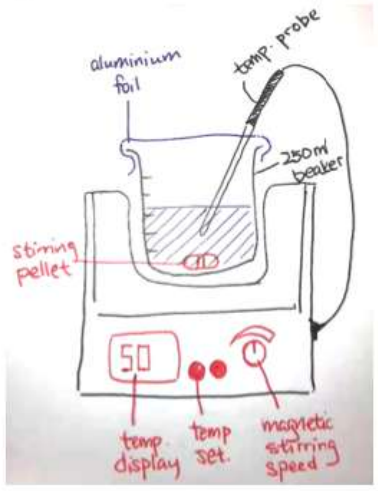


Diagram of experimental set up of one trial

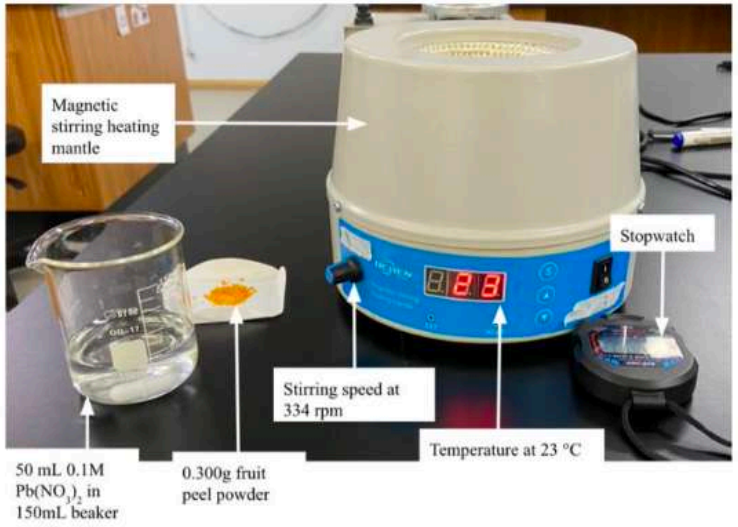


Figure 5: Experimental set-up for contact time between lead (II) nitrate solution and fruit peel powder

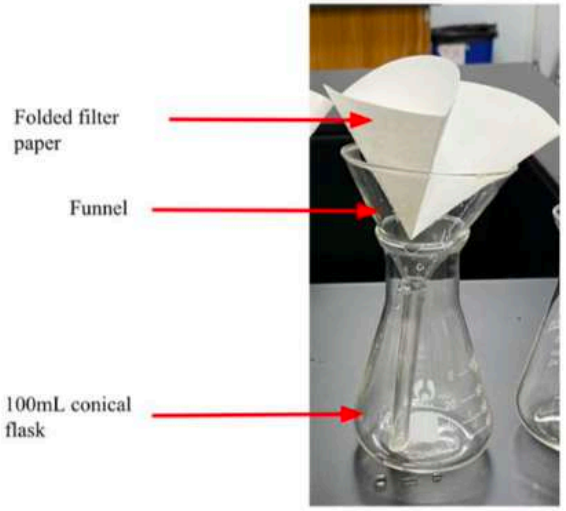


Figure 6: Experimental set-up for filtering fruit peel powder out of treated lead (II) nitrate solution

RAW DATA

- Raw data should be separated from processed data
- IV should be in leftmost column and DV (trials) should be on the right
- Units and uncertainty listed in column headers
- All data presented to same accuracy
- Outliers can be shown for further clarity

Analysis

Raw Data

Quantitative Data:

The initial and final pH are measured by pH meter and the difference between them is taken. The uncertainty of ±0.01 is obtained from the manual, and the uncertainty for the initial and final pH is added (±0.02) for the change in pH.

Table 1: pH for different concentrations of ammonium hydroxide after 7 hours

Concentration of ammonium hydroxide (mM±7.1%)	Initial pH (±0.01)	Trial 1		Trial 2		Trial 3		Trial 4		Trial 5	
		Final pH (±0.01)	**Δ pH (±0.02)**	Final pH (±0.01)	**Δ pH (±0.02)**	Final pH (±0.01)	**Δ pH (±0.02)**	Final pH (±0.01)	**Δ pH (±0.02)**	Final pH (±0.01)	**Δ pH (±0.02)**
0	6.68	6.41	**-0.27**	6.41	**-0.27**	6.23	**-0.45**	6.32	**-0.36**	6.23	**-0.45**
0.1	7.76	6.86	**-0.90**	6.94	**-0.82**	6.86	**-0.90**	6.86	**-0.90**	6.94	**-0.82**
1	9.58	7.90	**-1.68**	7.98	**-1.60**	7.98	**-1.60**	7.98	**-1.60**	7.98	**-1.60**
4	10.06	9.58	**-0.48**	9.74	**-0.32**	9.58	**-0.48**	9.58	**-0.48**	9.66	**-0.40**
7	10.20	9.82	**-0.38**	9.90	**-0.30**	9.82	**-0.38**	9.74	**-0.46**	9.90	**-0.30**
10	10.36	9.90	**-0.48**	9.90	**-0.48**	9.90	**-0.48**	9.90	**-0.48**	9.82	**-0.56**

Raw Data - Quantitative:

Table 1: Capsaicin mass (mg) vs duration of kimchi fermentation until achievement of optimal pH (4.5):

Capsaicin Mass (mg)	Time Elapsed (hours) (±0.01 seconds)				
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
0	37	37	37	43	37
1.875	46	67	74	66	60
3.750	69	66	46	60	55
5.625	69	57	58	60	49
7.500	53	75	58	60	66
9.375	63	66	82	55	55

**The raw data values were rounded to the nearest hour to allow easier analysis of data*

= outlier

PROCESSED DATA

- Processed data should not include trails as typically a mean will be calculated and used for graphing purposes
- A description can accompany table explaining what was calculated and how
- Statistical analyses should be explained and presented (full stats can be included in appendix if too lengthy) including alternative and null hypotheses

Analysis

Table 4: Effect of carbon dioxide on pH for different concentrations of ammonium hydroxide

Concentration of ammonium hydroxide (mM±7.1%)	Change in dissolved oxygen (±0.4mg/L)	Percentage of oxygen consumed compared to 0mM (%)	Change in pH (±0.02)
0	-2.63	100.0	-0.36
0.1	-2.60	99.0	-0.36
1	-2.87	109.1	-0.39
4	-3.41	129.8	-0.47
7	-3.82	145.4	-0.52
10	-4.84	184.0	-0.66

Sample calculation for 0.1mM :

$$\Delta pH of\ 0.1mM = \frac{\Delta DO\ of\ 0.1mM}{\Delta DO\ of\ 0mM} \times \Delta pH\ of\ 0mM = \frac{-2.60}{-2.63} \times (-0.36) = -0.354611... = -0.36\ (2SF)$$

The fraction including the ΔDO data indicates the effect of ammonium on change in DO. This is multiplied by the change in pH at 0mM to find the relative change in pH for each ammonium hydroxide concentrations.
This value is subtracted from the overall change in pH to get a relative scale of how much ammonium had the species absorbed.

In order to compare the biosorption efficiencies of the different fruit peels, Microsoft Excel was used to calculate the mean biosorption efficiency for each fruit peel type. Moreover, Microsoft Excel was also used to calculate standard deviation to determine the spread of the data. To determine whether the calculated standards deviations were high or low relative to the means, coefficient of variation ($CV = \frac{standard\ deviation}{mean}$) was calculated for every environmental group.

Table 6: Mean, standard deviation and coefficient of variation of Pb^{2+} ions biosorption efficiency of different types of fruit peel powders

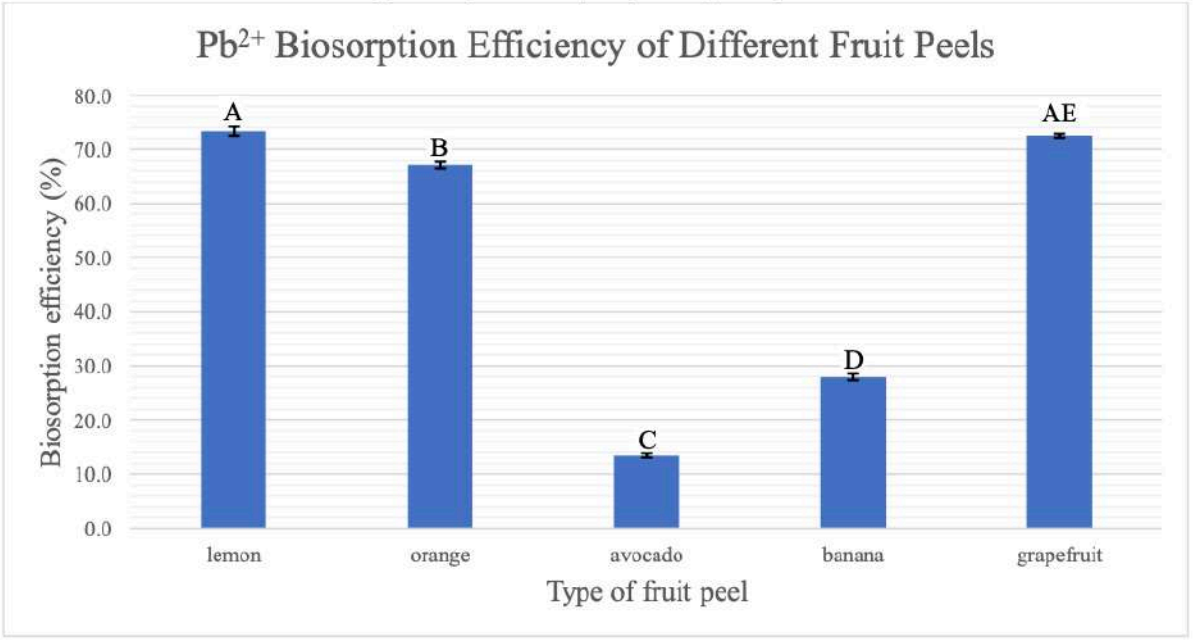
Type of fruit peel	Biosorption efficiency (%)		
	Mean	Standard deviation	Coefficient of variation
lemon	73.4	0.853	0.0116
orange	67.1	0.707	0.0106
avocado	13.5	0.390	0.0289
banana	27.9	0.606	0.0217
grapefruit	72.5	0.358	0.00494

GRAPH(S)

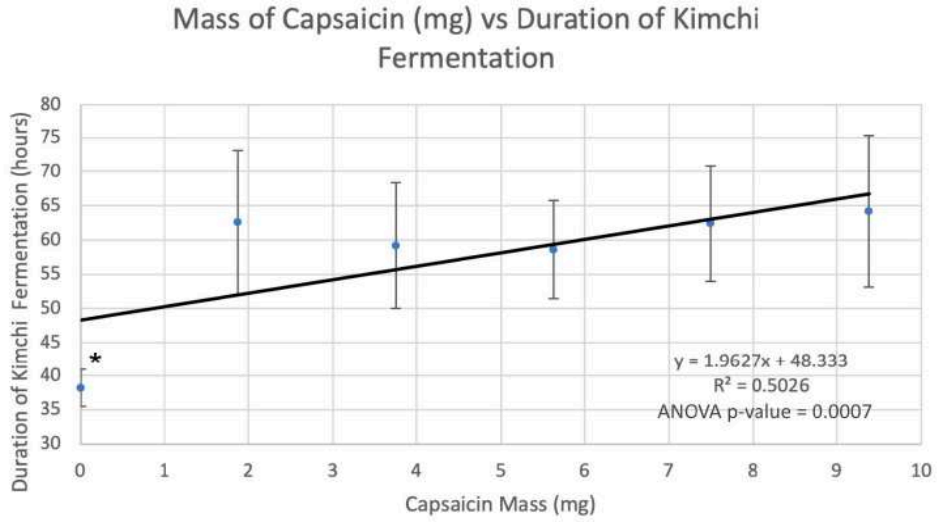
- Graph should contain a detailed caption (including error bar source and any other statistical tests)
- Axes labelled clearly with unit
- Legend (if necessary)
- Scaling appropriate
- Not blurry (especially important if they screenshot from LoggerPro as this can cause poor image quality)

Analysis

Graph 2: Mean Pb^{2+} ions biosorption efficiency of different types of fruit peel powder. Error bars were calculated from standard deviation. Means with different letters are significantly different (Tukey HSD $p<0.01$)



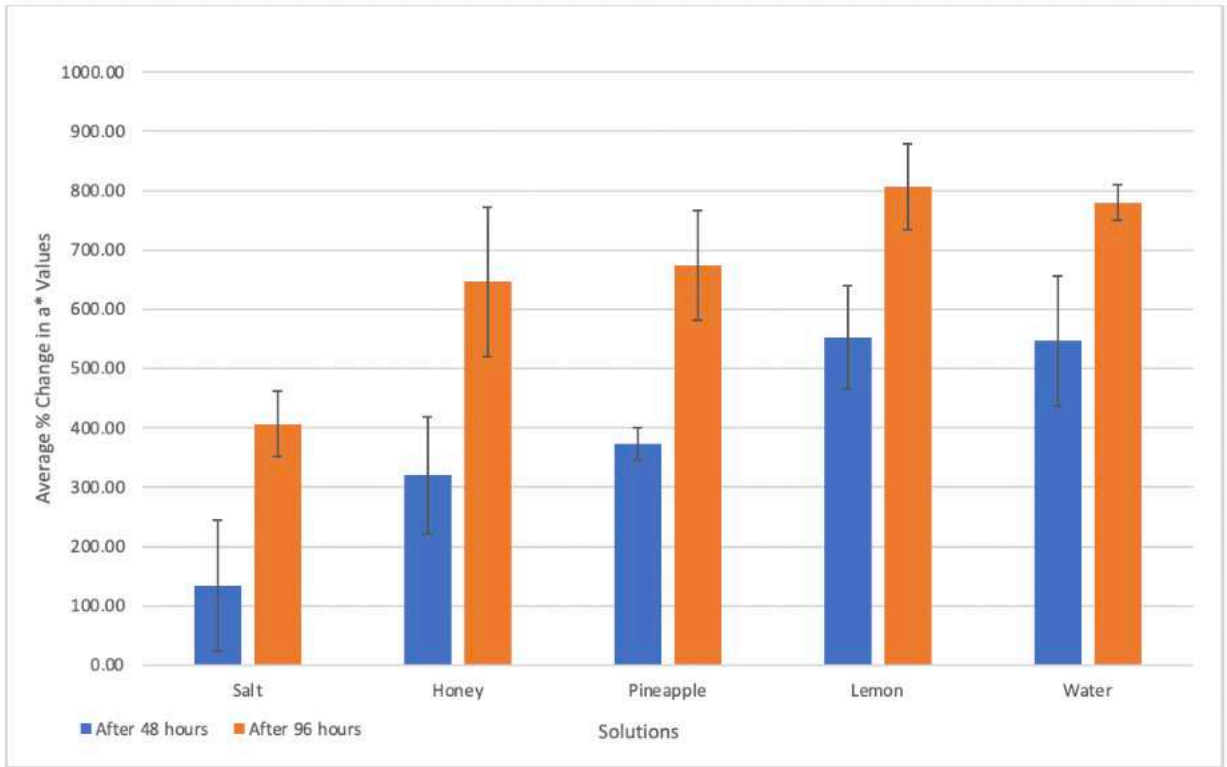
Graph 1: Capsaicin mass (mg) vs duration of kimchi fermentation until achievement of optimal pH (error bars were derived from standard deviation values seen in Table 2):



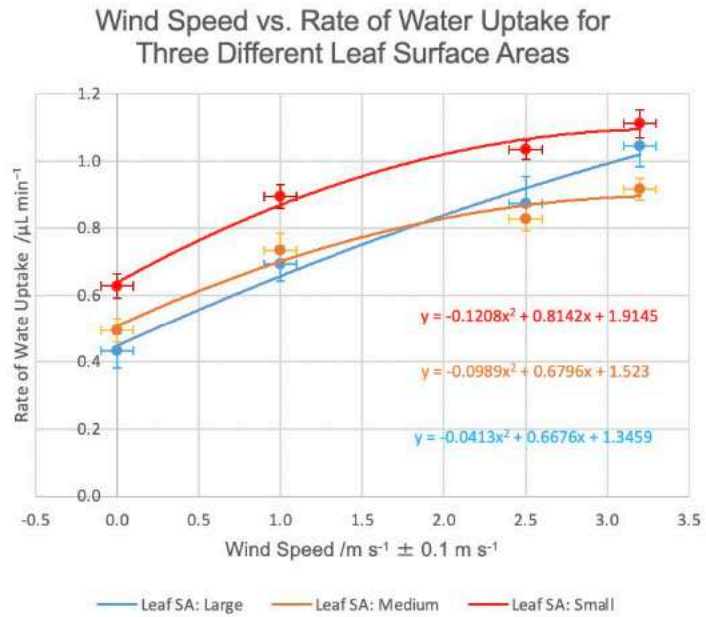
** denotes a group which is significantly different from other groups (Tukey HSD $p<0.05$ or lower)*

Graph 2: Mean Percent Change in a* Values

The graph plots the percentage change in a* values against different solutions the *Malus domestica* [Tsugaru](s) were immersed in for both 48 hours and 96 hours. The error bars for this graph were created from the STDEV shown in table 6 column 5.



Graph 1: The rate of water uptake of *Ficus umbellata* against wind speed for 3 different leaf SA of *Ficus umbellata*. The vertical error bars are from the standard deviation and the horizontal error bars are from equipment uncertainty of the anemometer. The quadratic equation was chosen as Line of Best Fit (hereinafter "LOBF") since increase in R_u per increase in wind speed should decrease at high wind speeds according to my hypothesis and logarithmic does not account for graphs that have y-intercept greater than or equal to 0.



ANALYSIS

Citing tables and graphs describe

- overall trends and specific differences among groups
- outliers (if any)
- Stats test (χ^2 / ANOVA + post-hoc and p values)
- do you accept or reject your null hypotheses based on p values
- error bars and St.Dev/CV - uncertainty in data

Analysis

Analysis

As seen in graph 2 and table 6, the lemon peel had the greatest biosorption efficiency at 73.4%. The lemon peel was followed by the grapefruit peel with a biosorption efficiency of 72.5%, the orange peel with a biosorption efficiency of 67.1%, and then the banana peel with a biosorption efficiency of 27.9%. Out of the five fruit peels, the avocado peel had the lowest biosorption efficiency with a biosorption efficiency of 13.5%. While the lemon, orange and grapefruit peels all have biosorption efficiencies that span across a relatively small range of 6.3% (67.1%-73.4%.), biosorption efficiency is significantly lower for the banana and avocado peel. The banana peel biosorption efficiency is 39.2% lower than the orange peel biosorption efficiency while the avocado peel biosorption efficiency is 53.6% lower than the orange peel biosorption efficiency. While the difference in biosorption efficiency between the banana and the avocado peel, 14.4%, is not as large, it is still greater than the difference between the lemon, orange and grapefruit peel biosorption efficiencies.

As seen can be seen in appendix 1, the p-value corresponding to the F-statistic of the one-way ANOVA test, 1.1102E-16, is lower than the critical value of 2.8660814. We can therefore reject the null hypothesis and accept the alternative hypothesis, meaning that the biosorption efficiencies of one or more treatments are significantly different, and thus that type of fruit peel does affect the efficiency of Pb^{2+} ion removal through biosorption. In graph 2 it can be seen that the error bars of the lemon biosorption efficiency and grapefruit biosorption efficiency overlap, suggesting that the biosorption efficiencies of these two fruit peels are not significantly different from each other. This is supported by the Tukey HSD test (see appendix 2) which showed that the Tukey HSD p-value of the lemon-grapefruit treatment pair was 0.231. As this p-value is greater than 0.01 (the significance level), there is no significant difference between the biosorption efficiencies of lemon and grapefruit peels. No other error bars overlap, indicating that the biosorption efficiencies of all other fruit peels are significantly different. This is supported by the Tukey HSD test (see appendix 2) which showed that the Tukey HSD p-values for all experimental group pairs –other than the lemon-grapefruit treatment pair– was lower than 0.01.

As can be seen in table 6 and the error bars in graph 2, the standard deviation for all experimental groups was very low relative to the data being collected. This is supported by the calculated coefficients of variation which are all less than 1. The standards deviations indicate that the data collected per fruit peel type did not have a lot of spread, suggesting that the method used was precise and that the collected data is reliable. As a result, there is a low uncertainty in regard to the collected data.

CONCLUSION

- Overall conclusion from results
- Explain conclusion using scientific theory with references from literature
- Re-state RQ and answer it
- Re-address original hypothesis
- Discuss strength of the conclusion based on stats, error, uncertainty (i.e. how sure are you of this conclusion)
- Re-address context/applicability in light of your results

Personal Engagement **Evaluation**

Conclusion

The graph with the trendline as well as the processed data shows that there is an increasing amount of ammonium absorbed by the species until 1mM and decreased significantly and flattened after 4mM. The low values in 4mM, 7mM, and 10mM may suggest that in highly concentrated solutions, the species could not absorb ammonium because of the toxicity of ammonium. The decrease in absorption after 4mM can be explained by the effect of ammonium toxicity at higher concentrations (20mM), that is further explored by a past study by Osaka University, in which the high ammonium concentration had significantly reduced the cyanobioants and chlorophyll in the plants. (Maejima, 2001). This may also explain why the plants had a slightly grey color instead of green color because chlorophylls are responsible for the green color in plants. On the other hand, species being able to absorb the ammonium the most at 1mM could be explained such that the ammonium had acted as a nutrient for the species, enhancing biological processes.(Allott, 2014). One other aspect of explanation is about the collision theory. As more particles present in the solution, the collision frequency increases, thus more ammonium is absorbed into the plants at a faster rate. The results also show there is a direct correlation between the decrease in dissolved oxygen and the concentration of ammonium hydroxide. This may be due to increased metabolism from ammonium absorption and damaged tissue repair by the ammonium, which requires more energy thus increased respiration.

To answer the research question: To what extent does the concentration of ammonium hydroxide (0.1mM, 1mM, 4mM, 7mM, 10mM) affect the ability of aquatic plant Ludwigia ovalis to absorb ammonium as measured by the change in pH over time?, the results show that as the concentration of the ammonium hydroxide increases, the ammonium absorption of *Ludwigia ovalis* increases until approximately 1.5mM, and decreases and flattens to 0 from then. This is similar to the alternative hypothesis that: 1) the ammonium absorption will exponentially increase at lower concentrations, 2) there is a optimum at 2.5mM, 3) the ammonium absorption will become plateau after the optimum, 4) the increase in ammonium absorption will slow down near optimum. However, the optimum concentration for *Ludwigia ovalis* and the range in which it can absorb ammonium (0mM to 4mM) is much smaller than predicted, as shown in figure 1 in hypotheses and graph 1.

Overall, the statistical tests together with error and uncertainty calculations, the data are precise with low random errors, and it shows a strong correlation of $p = 1.1102 \times 10^{-16}$ between the independent valuable, the concentration of ammonium hydroxide, and the dependent variable, the change in pH from ammonium absorption. This makes the results and the conclusion strong and confident. From this investigation, at least for *Ludwigia ovalis*, it could be planted in the region where the ammonium pollution is around 1mM to reduce the ammonium dissolved in water. But this does not solve the issue entirely because it cannot withstand higher pollution levels, such that the pollution in underground water can be up to 7mM (森本, 2016).

Conclusion:

Considering the analysis conducted on the results of the statistical tests used, it can be concluded that the presence of capsaicin in kimchi fermentation does impact the duration of kimchi fermentation until achievement of optimal pH of 4.5. Test groups containing some mass of capsaicin (>0mg) displayed significantly longer durations of fermentation. This can be explained by the antimicrobial effects of capsaicin, due to their ability to pose as a toxic agent that can deteriorate the structure of bacteria. Prior studies have used the species *Streptococcus pyogenes*, commonly known as group *A streptococcus*, which is known to have reacted to concentrations of capsaicin (Cichewicz et al, 1996). This information is relevant because *Streptococcus pyogenes* is a member of the order of LAB, the same type of bacteria observed in kimchi fermentation, so these studies can be linked through this relation. More specifically, it has been shown in prior studies that populations of LAB such as *Leuconostoc* and *Lactobacillus* were diminished in early stages of fermentation of kimchi that used gochugaru, as opposed to samples that did not contain any gochugaru in which their population number remained quite consistent throughout the entirety of the fermentation process (Cho et al, 2016). This can be used to explain how solely the presence of capsaicin in kimchi fermentation increases the duration of the process.

In reference to the research question, *To what extent can the concentration of capsaicin in gochugaru (Capsicum annuum) delay the time it takes for kimchi to reach its optimal pH of 4.5 during fermentation?*, it can be concluded that the presence of capsaicin does increase the duration of kimchi fermentation, but it cannot be determined from the collected data whether incrementally increasing its mass will further delay the process. When considering the alternative hypothesis, this conclusion partly supports it because although it was correct in identifying that the presence of capsaicin in kimchi fermentation would increase its duration until achievement of an optimal pH of 4.5, it specifies that increasing the mass of capsaicin will directly correspond to an increase in the duration of fermentation. The results of this experiment combined with its analysis reveal that the general presence of capsaicin will delay kimchi fermentation, but increasing its mass will not correspond to increased durations of the process. The alternative hypothesis was not supported in this investigation and is therefore overall incorrect.

This conclusion is supported by the data derived from the ANOVA and Tukey HSD tests observed in the appendices: Table 3 and 4. The p-value produced by the ANOVA test suggests that there is significant difference between some test groups, which is specifically supported by the Tukey HSD test, revealing that only the test group containing 0mg of capsaicin differed significantly from all other test groups in terms of average duration of fermentation. Furthermore, although the slope of the LOBF suggests a positive relationship between the independent and dependent variable, the r^2 value shows that the data is scattered and the data produced does not fully support the relationship indicated by the LOBF. This shows that overall, while increases in mass of capsaicin does generally result in longer durations of fermentation until achievement of 4.5 pH, there are fluctuations in the data that deviate it from the relationship set by the slope of the LOBF. Furthermore, the analysis of standard deviation values and outliers show that the conduction of the experiment suffers from random error, creating a notable amount of uncertainty in regard to the collected data. This would suggest that the only deciding factor between the groups was purely the presence of capsaicin in the fermentation process.

In context of the fermentation of kimchi, the results derived from this experiment are not so useful. Although a significant difference was detected between some groups, it only involved the group with 0mg of capsaicin, meaning no gochugaru was used in the kimchi batch (white kimchi). However, even though the experiment did not achieve the set hypothesis and provide information on how to produce better quality red kimchi, it justifies why red kimchi is more popular than white kimchi, since its longer average duration of fermentation allows it to develop stronger, richer flavors.

1. Overall conclusion

2. Explain results scientifically

3. Re-address RQ and hypothesis

4. Strength of conclusion

5. Context and application

Conclusion

Considering the results of the one-way ANOVA test and the Tukey HSD test, it can be concluded that lemon and grapefruit do not significantly differ in biosorption efficiency and that they have the greatest biosorption efficiency. Orange peel has the second greatest biosorption efficiency and its biosorption efficiency is close to that of the grapefruit and the lemon peel. The similar biosorption efficiencies of the grapefruit, orange and lemon peel can be explained by these three fruits all being citrus fruits and thus having similar peel compositions. The high biosorption efficiencies of the citrus fruits can be explained by the high amounts of pectin in these fruit peels which contain hydroxyl and carboxyl functional groups. Hydroxyl is polar and carboxyl is charged; therefore, both functional groups can undergo ion exchange with Pb^{2+} ions. (Kanamarlapudi et al., 2018) Moreover, as previously mentioned in the hypothesis, citrus fruit peels are highly porous and thus have a high surface area over which means that ion exchange and complexation between the functional groups and the Pb^{2+} ions can occur. (El-Naggar et al., 2018) The slightly lower biosorption efficiency of the orange peel is likely due to its relatively lower pectin content of 2.34–2.38%, while lemon peels have a pectin content of 2.80–2.99% and grapefruit peels have a grapefruit content of 3.30– 4.50%. (Baker, 1997) The banana peel had a biosorption efficiency that is a lot smaller than that of the three citrus fruits. This result is in tandem with a prior study which found that lemon and orange peel showed better biosorption capacity in lead removal than banana peels. (Kelly-Vargas et al., 2012) This is likely due to the non-porous nature of banana peels. Of the five tested fruit peels, avocado has the lowest biosorption efficiency. This could be due to the relatively high mineral content of avocado peel, thus resulting in lower functional group content. (Rotta et al., 2015) Banana peels have a higher biosorption efficiency than avocado peels due to banana's high lignin content, a component of plant cell walls that has a high amount of hydroxyl functional groups. (Khawas & Deka, 2016)

To refer back to the research question of this investigation, *How does the type of fruit peel (lemon, orange, avocado, banana and grapefruit) affect the percent removal of lead ions (Pb^{2+}) from water (biosorption efficiency)?*, it can be concluded that lemon and grapefruit show the greatest biosorption efficiency and that avocado and banana peels show the lowest biosorption efficiency. Orange peels also have a high biosorption efficiency, but it is slightly less than the biosorption efficiencies grapefruit and lemon peels. Based on this conclusion and with omission of one minor difference, the hypothesis was supported. The difference was that the hypothesis predicted that all three citrus fruits would have similar biosorption efficiencies, but the results show that the biosorption efficiency of grapefruit and lemon is slightly higher. Regardless, the general hypothesis of grapefruit, lemon and orange peels having similar biosorption efficiencies due to the similar structure and composition of citrus peels, was correct.

This conclusion is strong considering that the results of the ANOVA and Tukey HSD test have shown the significant difference in the biosorption efficiencies of the studied fruit peels. Other than the difference in biosorption efficiency between lemon and grapefruit, the findings of these statistical tests show a high level of significance, thereby strengthening this investigation's conclusion. The p-value of the one-way ANOVA test was 1.1102E-16. This means that if there was no significant difference between the biosorption efficiencies of the fruit peels (i.e. if the null hypothesis were true), only 1.1102E-14 % replicates of this study would obtain the observed differences in biosorption efficiencies due to random sampling errors. The p-values of the Tukey HSD tests were also low, with the p-values being less than 0.01. Again, this also suggests that there is a low probability of the observed difference in biosorption efficiencies being due to random errors as opposed to actual differences in the biosorption capacities of the fruit peels. Moreover, in regard to the biosorption efficiency of the citrus fruits and banana, this conclusion is supported by prior studies. (Baker, 1997) (Kelly-Vargas et al., 2012) The conclusion in regard to the biosorption efficiency of the avocado peel is, however, less strong due to the lack of prior scientific studies into the functional group composition of avocado peels and a lack of comparative studies into avocado's biosorption efficiency of Pb^{2+} ions. Further testing would be required to determine whether avocado is in fact significantly less effective at removing Pb^{2+} ions from polluted water sources.

In the context of treating lead pollution of water sources in China through biosorption, the results of this investigation suggest that the use of grapefruit or lemon peels as biosorbent are the best choices. Considering that lemons are cheaper and more widely available in China than grapefruits, the use of lemon peels is more favourable as it has a lower cost. (Zang, 2020) As there is only a slight difference between the biosorption efficiency of orange peels and that of lemon and grapefruit peels, orange peels are also a good option for Pb^{2+} ions removal, especially seeing that oranges are more readily available in China than grapefruits. Although banana and avocado peels can remove Pb^{2+} ions from polluted water, doing so is not suggested based on the results of this investigation considering that investments in water treatment should be directed at the most effective treatment options.

EVALUATION - STRENGTHS

- Often forgotten by students!

Areas to include

- Number of trials/data set – should relate to St Dev value
- Novelty of data (not previously studied or expanding upon prior work)
- Potential applicability of findings
- Low p-values (if applicable)
- Low St Dev/CV/outliers (if applicable)

Evaluation

Strengths

1. 5 trials were conducted per fruit peel. This increased the reliability of the results of this experiment as it decreased the effect of random errors while also enabling data analysis through statistical tests. The low relative standard deviation per experimental groups indicate that 5 was an appropriate number of repeats.
2. This investigation directly compared the biosorption efficiency of different fruit peels. This type of direct comparison of more than two fruit peels is generally missing from current scientific research on the use of fruit peels to remove Pb^{2+} ions from contaminated water sources, therefore, the data produced by this experiment are novel and provides valuable new knowledge.
3. The low relative standard deviation across trials of all fruit peel types indicate precise results as a result of a method with low occurrence of random errors due to control variables being controlled properly.
4. The low p-values of statistical tests enables for conclusions of this investigation to be drawn with a high degree of certainty considering that there is only a small probability that observed significant differences between the biosorption efficiencies of the studied fruit peels would have occurred due to random errors.

Strengths:

- A control group that did not contain any capsaicin was used alongside the five other test groups that contained some level of capsaicin, isolating it from the variables changed in other groups. This allows for a better analysis of the collected data because the test groups that do contain capsaicin can be compared with the group that does not in order to determine whether the variable changed (capsaicin mass) has impact on the test groups.
- The intention of this experiment was to validate the relationship between capsaicin mass and duration of kimchi fermentation and establish a method for extending the time for fermentation to produce better quality kimchi. This is important in the scientific community because given prior studies that have been explored in preparation for this investigation, the relationship between capsaicin mass and duration of kimchi fermentation is not well documented, providing novel and valuable information to the scientific community.
- The potential application of the information produced by this information can be useful for many homemade kimchi fermenters who are curious to understand how better quality kimchi can be created. By applying the traditional methods of creating kimchi to a scientific basis to understand the biology behind the fermentation process, this investigation allows people to objectively understand what factors are at play in determining the quality of kimchi, making the knowledge produced from this investigation valuable.
- The low p-value of the ANOVA test allows a conclusion for this investigation to be formulated with some degree of certainty that suggests that the presence of capsaicin does impact the duration of kimchi fermentation to a certain extent.

EVALUATION – WEAKNESSES + SUGGESTIONS FOR IMPROVEMENT

- Every weakness/limitation listed should be accompanied by a specific suggestion for improvement
- Weaknesses should be related to methodological (systemic) errors such as apparatus, IV range, method of measurement, duration, etc. Random errors can be addressed with increased repeats/trials
- Limitations and constraints due to lack of time / equipment / availability can be included also
- From the results, what should be examined next and why?

Evaluation

Weaknesses

Weaknesses / Limitations	Improvement
The dependent variable is measured through pH, not the ammonium concentration, and the pH change by ammonium absorption is calculated through subtracting and multiplying pH, which is a significant systematic error. pH is logarithmic, so it also could be erroneous to subtract or do any calculations like a normal rational number. This is done because there was no TAN kit available in the school laboratory setting.	Ammonium concentration dissolved in water could be measured by a specific water-test kit that could measure TAN (total ammonium nitrogen). (Francis-Floyd, 2015). Additionally, from a study from University of Florida, temperature and pH could be measured to determine unionized ammonium, which is 10 times more deadly than the ammonium hydroxide.
The range of independent variables was too wide, creating a 3mM gap between the most absorbed region (1mM) and the flat region (from 4mM).	To determine the concentration in which *Ludwigia ovalis* could perform the best, more groups and trials are needed between 1mM and 4mM, especially 1.5mM 2mM, and 2.5mM since it is near the optimum.
The time period of absorption is 7 hours, a time period before school and afterschool, due to time constraints. A longer time period could be set, but it is not probable to keep the air conditioning on for 24 hours and restrict temperature fluctuations, especially when the outside temperature is lower than the room temperature.	If the plants had grown for 4-6 weeks (Maejima, 2001), then an appropriate time for measuring would be around 2 weeks. The previous studies had measured ammonium absorption over 2-3 weeks (Maejima, 2001) and 23 days (SCHJØRRING, 1986).
Photosynthesis of the species is restricted, which is detrimental to plants because photosynthesis allows plants to create ATP, which is the energy source for cellular respiration and other biological processes. Limiting photosynthesis does not model the real environment the plants are facing.	The main reason for the prohibition of photosynthesis is to measure pH more accurately, so if a TAN test kit is used, the experiment can be conducted under the sun, allowing more natural conditions, making the results of the investigation to be more applicable.
Relatively small or immature plants are used because it was only obtainable in a short period of time with low price. This could be different to those adult plants in which there is more strength and tolerance developed.	If applicable, grow or use more mature plants that had been growing for at least a month, so that the plants could show their full capacity and tolerance against certain ammonium concentrations.

Future Directions / Extensions

This investigation showed that at least for species *Ludwigia ovalis*, the ammonium absorption increases as the concentration increases, if it is within the tolerable condition. This would potentially solve the river pollution by ammonia if these native species are planted more near the pipes in the rivers. However, if planted excessively, it will lead to eutrophication and destroy the habitat, so further studies about the effect of ammonia on the growth as well as the rate of ammonium absorption and the effect of other minerals or organisms present in the polluted areas need to be conducted to further expand this horizon.

Weaknesses/limitations

1. Although the size of particles in the fruit peel powder was controlled through ensuring that the width of all powder particles was smaller than 0.5mm with a caliper, the particles still differed in size, as can be seen in figure 3. As a result, the surface area available for biosorption per fruit peel treatment likely differed. As rate of biosorption is determined by the interactions between the Pb^{2+} ions and the functional groups at the surface of the fruit peel, this would have likely affected biosorption efficiency.
2. Data collection for this investigation were completed over the duration of one week with the same fruit peel powders used throughout. The fruit peel powders were prepared 1.5 weeks prior to this week of data collection. Pectin degrades over time; therefore, although the fruit peel powders were stored in air-tight Ziploc bags, some of the functional groups may have been lost, reducing the biosorption efficiency of the fruit peel powders; especially of lemon, grapefruit and orange due to their high pectin content. This investigation's preparation and data collection could not be completed within a shorter time frame due to time constraints.
3. The initial concentration of Pb^{2+} ions used in this investigation does not reflect the actual concentrations of Pb^{2+} ions present in contaminated water sources. Considering that initial concentration of Pb^{2+} ions effects the rate of biosorption (see explanation in controls table), the biosorption efficiencies of the fruit peel powders in their real-world application may differ from the results produced in this experiment.
4. After removing the lead (II) nitrate solution from the magnetic stirring heating mantles, the fruit powder was still in contact with the lead (II) nitrate solution while filtering out the fruit powder. As a result, the contact time between fruit peel powder and lead (II) nitrate solution was not kept constant at 60 minutes for all trials. Especially since filtration time varied, ranging from less than a minute to six minutes.
5. In the context of using biosorption as a solution for lead pollution of water sources, it is highly unlikely for Pb^{2+} ions to be the only metal cations present considering that other metal cations may exists in the polluted water source naturally or also as the result of pollution. The presence of other cations would affect the interactions between the Pb^{2+} ions and the functional groups in the fruit peels, thus influencing the rate of biosorption. Depending on the specific properties of the functional groups in fruit peels, certain fruit peels may interact more strongly with certain metal cations. Therefore, the conclusion drawn in this investigation may not hold true when applied to the removal of Pb^{2+} ions from polluted water in the presence of other metal ions.

Improvements

1. After blending fruit peels into a fine powder, the powder should be passed through a sieve to filter out all particle sizes below a certain threshold, such as 1mm or 0.5mm for instance. This would be a more reliable way of measurement than having to measure each particle visually through the use of a caliper.
2. Fruit peel powder could be stored in a refrigerator between 2°C- 5°C as the low temperatures would slow down the degradation of the fruit peel and therefore preserve the functional groups.
3. As opposed to increasing concentration as a means of speeding up the rate of adsorption and thus the overall reaction time, a different variable, such as the mass of fruit peel powder used or temperature, could be increased so that concentration could be kept low to better represent actual Pb^{2+} ion concentrations in polluted water sources.
4. Preliminary trials could be conducted to determine the mean time of filtration. Then, based on this, the lead (II) nitrate solution could be removed from the magnetic stirring heating mantles after a shorter period of time so that the filtration time is considered in the overall contact time between the lead (II) nitrate solution and the fruit peel powder.
5. In addition to Pb^{2+}ions, other metal cations that are commonly found in polluted water sources, such as Cu^{2+}ions, could be incorporated into the solution from which the fruit peels are absorbing metal cations. This would mean that UV-vis spectrophotometry could no longer be used to measure the final concentrations of Pb^{2+}ions as the Beer-Lambert law would no longer be applicable seeing that the Beer-Lambert law describes the absorbance of one chemical species. Instead titration could be used to determine the concentration of Pb^{2+}ions.

Further Directions

As mentioned in the controls, physical pre-treatments of fruits peels are often employed as a means of maximizing biosorption efficiency. There are, however, also chemical pre-treatments available such as acid washing. (Kanamarlapudi et al., 2018) Most often, these treatments are used to ionize the cellulose compounds in the fruit peel so that the peel becomes negatively charged, thereby increasing the electrostatic attraction between the fruit peel and the metal cations. A study could be done to investigate the effect of different chemical treatments on the biosorption efficiencies as to further maximize the rate of biosorption of Pb^{2+}ions by fruit peels. Another possible way to enhance this investigation would be to study a different heavy metal to determine whether the discovered trends pertaining to the biosorption efficiencies among the studied fruit peels are specific to Pb^{2+}ions or whether they are the same for all heavy metal ions. This study would still relate to the tackling water pollution as heavy metals are common pollutants due to their frequent industrial use.

WORKS CITED

- In the format of the student's choosing – as long as its consistent
- Many online citations tools:

Calvin.edu

Citethisforme.com

- How to cite scientific papers: ***guide***
- Strongly advise students to create a working document of all of their sources as they find them

* Few sources from non-scientific sources is a bad sign and can be addressed in PE

Works cited:

Ahmed Said, J. (2017). undefined. *Journal of Agronomy*, *16*(4), 138-146. https://doi.org/10.3923/ja.2017.138.146

Ali, A. S., & Elozeiri, A. A. (2017). Metabolic processes during seed germination. In *Advances in seed biology*. IntechOpen. https://doi.org/10.5772/intechopen.70653

ASTA. (2014). *The guide to seed treatment stewardship*. https://seed-treatment-guide.com/wp-content/uploads/2014/12/ASTA-Seed-Guide-Farmers.pdf

Berhanu, A. T., & Berhane, G. (2014). The effect of salinity (NaCl) on germination and early seedling growth of lathyrus sativus and Pisum sativum Var. abyssinicum. *African Journal of Plant Science*, *8*(5), 225-231. https://doi.org/10.5897/ajps2014.1176

Boone, F. (2018). *Sea-level rise and groundwater salinization in the coastal area of Zeeland*. University of Amsterdam.

Chauhan, A., AbuAmarah, B. A., Kumar, A., Verma, J., Ghramh, H. A., Khan, K. A., & Ansari, M. J. (2019). Influence of gibberellic acid and different salt concentrations on germination percentage and physiological parameters of oat cultivars. *Saudi Journal of Biological Sciences*, *26*(6), 1298-1304. https://doi.org/10.1016/j.sjbs.2019.04.014

Cornea-Cipcigan, M., Pamfil, D., Sisea, C. R., & Mărgăoan, R. (2020). Gibberellic acid can improve seed germination and ornamental quality of selected cyclamen species grown under short and long days. *Agronomy*, *10*(4), 516. https://doi.org/10.3390/agronomy10040516

Doperwt verliest terrein op Nederlandse akkers. (2017, July 28). NOS. https://nos.nl/artikel/2185352-doperwt-verliest-terrein-op-nederlandse-akkers.html

Dove, N. (2010). *The Effect of Increasing Temperature on Germination of Native Plant Species in the North Woods Region*. University of Vermont. https://underc.nd.edu/assets/156376/fullsize/dove2010.pdf

El-Shraiy, A. M., & Hegazi, A. M. (2009). Effect of Acetylsalicylic Acid, Indole-3- Bytric Acid and Gibberellic Acid on Plant Growth and Yield of Pea (Pisum Sativum L.). *Australian Journal of Basic and Applied Sciences*, *3*(4). https://doi.org/3514-3523

Erdei, N., Barta, C., Hideg, É., & Böddi, B. (2005). Light-induced wilting and its molecular mechanism in epicotyls of dark-germinated pea (Pisum sativum L.) seedlings. *Plant and Cell Physiology*, *46*(1), 185-191. https://doi.org/10.1093/pcp/pci012

FAQ

1. What if the report is over 12 pages?

- This can be addressed in COMM (focus)
- Not like the EE, we read all included content (not necessarily appendix)
- However, if report is lengthy due to complexity, and all included material is relevant, student can still score 4 in COMM (imo)

2. Should students include an appendix?

- Technically, no. Examiners do not need to read the appendices
- Material that goes here should be additional (a lot of data, stats, pictures) and not crucial to the report.

3. What about margins and font?

- nothing specified in the guide. I encourage students to manipulate margins in order to prevent formatting issues and reduce page count. Font should be at least 11 (imo)

FIRST DRAFT – COMMON MISTAKES

RQ too vague

→ RQ should include all aspects of the investigation: IV, DV, and study species, location, and time period (if appropriate),

How does varying directional wind speed impact transpiration rate in Ficus umbellata differently for various leaf surface areas?

My feedback

Good start but you can be more specific for your IV and DV:

- Include what ranges you are testing for both of your IVs – makes it clearer
- Include how you are measuring this rate of transpiration, i.e. tool

Final version

How does varying directional wind speed (0.0, 1.0, 2.5, 3.2 m s-1) impact transpiration rate (µL/min) in *Ficus umbellata* differently for various leaf surface areas (small, medium, large) as measured by rate of water uptake using a potometer?

FIRST DRAFT – COMMON MISTAKES

RQ too vague

→ If short forms are used, they should be defined in the question to make it easier to interpret

What everyday ingredient (water, salt, honey, pineapple juice, lemon juice) diluted in distilled water to create 10% solutions, best inhibits amount of browning in Malus domestica measured via changes in L*a*b* and RGB values?

My feedback

- "everyday ingredient" should be reworded to something more specific
- Species name should be italicized. Variety?
- L*a*b* and RGB should have what they stand for, perhaps in brackets? this makes it easier to understand

Final version

To what extent does distilled water and 10% solutions of easily obtainable ingredients (salt, honey, pineapple juice, and lemon juice), inhibit the amount of browning in *Malus domestica* [Tsugaru] as measured by changes in L*a*b* (lightness, redness, yellowness) and RGB (red, green, blue) values?

FIRST DRAFT – COMMON MISTAKES

Introduction has poor flow

→ The introduction should logically connect one concept to another

→ Should contain detailed biological theory related to your investigation, i.e. if you are investigation photosynthesis – explain this

There should be a clear link between PE/context to prior studies and then to investigation so it is clear why this study is being done. Every aspect should be clearly justified in order to give reader confidence in the design.

Sample structure

1. Context – i.e. why should we care (pollution and impacts, improvement in an aspect of life, testing a cultural practice, little known in literature)
2. Biological theory – Explain in detail any aspects being studied (ex: if studying impact of pollutant on plant growth, explain how this chemical can impact this specifically and what factors can influence plant growth generally and why)
3. Prior studies – what is currently known in the literature about this. Outline past studies/results. Any gaps? What can your investigation extend or do differently?
4. Study species/location of study – why is this species chosen for this investigation?
5. Aim – overall, what do you hope to accomplish/find out in this investigation and why?

FIRST DRAFT – FEEDBACK EXAMPLE

Your background has a good base but it lacks biological theory and citations.

The background could be even easier to follow and more organized with the use of subheadings. This will make it more clear as to the flow of the background and the formation of the aim and RQ more organic.

I suggest you reorder your introduction to the following:

1) Organic wastes in aquatic systems
Introduce your context: organic wastes being dumped in aquatic bodies. What are organic wastes? Why is this occurring? Where is this occurring? Specifics examples in Japan to make this more relevant to your study. Generally, why is this a problem?

2) Impact of Ammonium wastes
Specifically discuss Ammonium as a waste in aquatic systems. Where is it coming from? Biologically, how does ammonium impact organisms and the environment? Be detailed here.

3) Application of plants in waste removal
How can plants be used to mitigate this issue? Past studies. Again, be specific and discuss the biology of the processes at play

4) Study Species
Clearly justify the choice of Ludwigia ovalis as the study species to investigate this process. Explain how it is an ideal candidate and link it to past studies, local relevancy (Japan), etc. The reader should understand why this plant was chosen and how it could be a valid candidate for addressing this issue.

FIRST DRAFT – FEEDBACK EXAMPLE

I suggest breaking up this background into sections with subheadings - it will make it easier to read and follow. Ideally, when constructing an introduction you want the reader to understand the biology and theory of what you are doing and understand why you are investigating what you are doing.

Sections I would suggest

1) Baking with yeast. Brief history of this process. Why this process is important etc. How can this process be improved?

2) Biochemical theory of yeast fermentation. How does it work in detail. How can respiration be measured?

3) Prior studies on using different saccharides and how this can influence the rate of fermentation.

4) How you are adopting/changing things. I.e. how is your study novel?

This leads to your aim organically

FIRST DRAFT – COMMON MISTAKES

Choice of Variables are not justified

The experimental groups of your IV should be justified
Why this range (why this max/min)?

- Why these increments?
- Does it makes sense for your context (does it simulate realistic/theoretical values)?
- Have these values been tested previously?
- Does it make sense for your study species?

The DV should be justified

- Why is this method of measurement appropriate? Are there alternatives?
- Has this method been used previously? Is it accepted/well-known?
- Are you adapting this method in some way? Why?

These justifications should be supported by scientific references (past studies, biological theory, etc.)

FIRST DRAFT – COMMON MISTAKES

Control variables are vague

Original

Variable	*Impact*	*Method of control*
temperature	If temperature of solution is different, than adsoption of lead ions will be impacted, making test unfair	Thermometer will be used to monitor the temperature change

Temperature of what? Specify

Need to specifically explain why temperature can impact your DV, in this case adsoption of Pb ions by fruit peels. Should be supported by scientific literature

Thermometers don't regulate temperature. What apparatus will you use to keep temp constant? What temp? Why?

Variable	Impact	Method of control
Temperature of lead (II) nitrate solution	Several prior studies have shown that temperature cans significantly affect the rate of adsorption by fruit peels. (Sharma, 2014) (Obi & Njoku, 2015) (Annadurai et al., 2003) Specifically, an increase in temperature results in an increase in the rate of adsorption considering that the number and size of active pores in the fruit peel's surface increases; thus increasing surface area and enabling more Pb^{2+} ions to be adsorbed.	Magnetic stirring heating mantles were used to keep the temperature constant at 23 °C. This temperature was chosen as it is a temperature at which all 5 fruit peels being studied can undergo biosorption. This was shown by a prior study on the effects of temperature on the biosorption capacity of different fruit peels. (Horsfall Jnr & Spiff, 2005)

Final version

FIRST DRAFT – COMMON MISTAKES

Formatting errors

- Page numbers (if title page is used, this is NOT numbered)
- Writing in 3rd person passive whenever possible. 1st person minimized but can be present (PE)
- Figure captions – every picture/diagram/table/graph should have a name (figure 1) and corresponding caption (outlining what it is)
- Tables break pages – if a table ***NEEDS*** to break a page than restate the column headers to make the table clear and easy to read
- Table column headers – include name (± unit)
- Accuracy of values presented
  - ➢ should be same as uncertainty listed (if ±0.1cm then data should be 2.1 not 2 or 2.11)
  - ➢ should be all the same (even if 0, list as 0.0)
- Graphs
  - ➢ Source of error bars should be included in caption as well as any stats
  - ➢ Axes labelled with units, not blurry (especially if imported), appropriate scaling and tick marks