SASTA OLIPHANT SCIENCE AWARDS

SOUTH AUSTRALIAN SCIENCE TEACHERS ASSOCIATION

Prize Winner

Scientific Inquiry

Year 5-6

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Magill School

The Rate of Reaction of Calcium Carbonate Dissolving in Acetic Acid

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Scientific Report

Title

The Rate of Reaction of Calcium Carbonate Dissolving in Acetic Acid

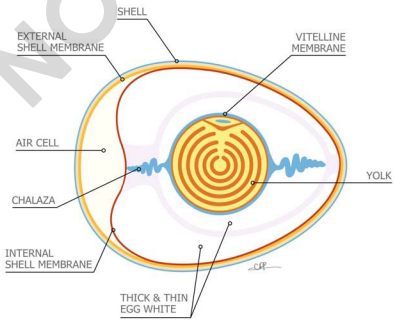
Research Question

How fast will the eggshell dissolve in vinegar at three different temperatures and two different concentrations of vinegar?

Background Information

Vinegar is a sour-tasting liquid produced through the fermentation of ethanol by acetic acid bacteria. Vinegar contains acetic acid of which the chemical formula is CH_3COOH. Acetic acid has a PH of around 2.5 and a molecular weight of 60g/mole.

An eggshell is a thin, hard outer layer of an egg that is made of calcium carbonate (CaCO3). Although eggshells are considered brittle, they help the egg to prevent bacteria from getting in.



Source: The eggshell: structure, composition and mineralization

When a raw egg is placed in white vinegar, the eggshell will dissolve. When calcium carbonate reacts with acetic acid, the end products are calcium acetate, water and carbon dioxide gas (Figure 1).

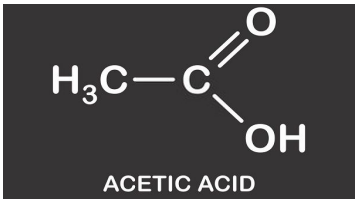
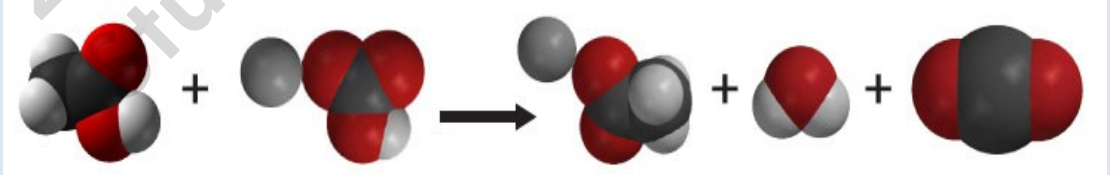


Figure 1. The chemical equation of the acid base reaction



$$2\ CH_3COOH_{(aqueous)} + CaCO_{3\ (solid)} \Rightarrow Ca(CH_3COO)_{(solid)} + H_2O_{(aqueous)} + CO_{2\ (gas)}$$

Acetic acid + Calcium carbonate ⇨ Calcium acetate + Water + Carbon dioxide

Aim

This experiment investigates the rate of reaction of calcium carbonate dissolving at three different temperatures, and two different concentrations of the acetic acid. Qualitative and quantitative analysis on the deshelled eggs is conducted to observe the effect of osmosis.

Hypotheses

It is hypothesised that, the higher the temperature is, the faster the eggshell dissolves in vinegar, and vice-versa. When warmed, the acetic acid molecules obtain more energy, and consequently, the chemical reaction progresses faster. Secondly, the higher the concentration of the vinegar is, the faster the eggshell dissolves in vinegar because more acetic acid molecules react with the calcium carbonate at a given time.

Variables

Independent Variables

The temperature and the concentration of the vinegar are the independent variables.

Dependent Variables

The time taken for the eggshell to dissolve in vinegar is the dependent variable.

Controlled Variables

Controlled Variables are to ensure that this experiment is a 'fair test' (Table 1).

Table 1. Controlled Variables

Controlled Variables	Method of Control	Effects on the Experiment
The amount of vinegar for each glass	The amount of vinegar for each glass is the same (180g) and weighed using a digital scale.	Different amount of vinegar dissolves the eggshell at a different rate.

The size of each glass	All the glasses are identical in size and of the same brand.	Glasses do not react with vinegar. The glass size is identical to ensure that the liquid level is the same.
The weight of the eggs	All the eggs are identical in weight (60g) and of the same brand.	The eggs of the same weight are selected to ensure the total surface area of the eggshell is the same. The increased total surface of the eggshell may increase the rate of reaction. Besides, the thickness of the eggshell should be considered too. The thicker it is, the more time is required to dissolve.

Uncontrolled Variables

The temperature which is not controlled and varies daily may affect the time taken for the eggshell to dissolve. However, there is no intention to conduct this experiment at a fixed temperature, and therefore there is a varied range of temperatures for which the eggshells to be placed.

Equipment and Materials

1. 6 raw eggs of the same weight (60g)

2. White vinegar (4% and 8% concentration of acetic acid)

3. 6 glasses of the same size

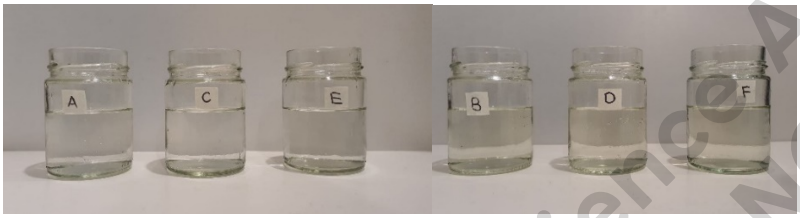
4. Thermometer

5. Digital scale
6. Fridge
7. Slow cooker (warm setting)

Procedure

1. Make sure each glass is dry and rinse each glass with vinegar to prevent dilution

2. Fill each glass with 180g white vinegar.



3. Place 6 raw eggs in each glass carefully.
4. Label each glass appropriately (Table 2).
5. Place the six glasses with the eggs at three different temperature settings
6. Record the temperature using a thermometer.

Table 2. The eggshells are labelled.

Label	Temperature	Concentration of Vinegar
A	room temperature (8 °C – 17 °C)	4%
B	room temperature (8 °C – 17 °C)	8%
C	low temperature (2.3 °C – 3.5 °C)	4%
D	low temperature (2.3 °C – 3.5 °C)	8%
E	high temperature (50.9 °C – 72.3 °C)	4%
F	high temperature (50.9 °C – 72.3 °C)	8%

Risk Assessment

Safety Precautions

During the experiment, chemical contacts were avoided by putting on an apron, gloves, and safety goggles. All equipment including the digital scale was kept dry and clean. The digital scale and thermometer were examined for any damage before and after use. The glasses were taken to the three different settings with care to prevent spilling. Any spilled substances were cleaned and removed instantly. The slow cooker was inspected for electrical safety to reduce the risk of electrical hazards. Hands were dried before turning on the switch to prevent electrical shocks. Furthermore, the glasses were carefully placed in the slow cooker to prevent scalds from hot water.

Environmental Consideration

There are no significant environmental considerations as the equipment and actions used in this experiment presented no hazard or danger to the environment.

Ethical Consideration

The unfertilised eggs used in this experiment are considered non-living things. There was no other living organism used in this experiment. As the eggs and the vinegar are also considered food, they are wasted for this experiment.

Processing and analysing data and information

Data Observation

The acid-base reaction between the acetic acid and the calcium carbonate which produces calcium acetate, water, carbon dioxide gas was observed (Figure 2, Table 3).

Photos of eggshells A to F under experiment

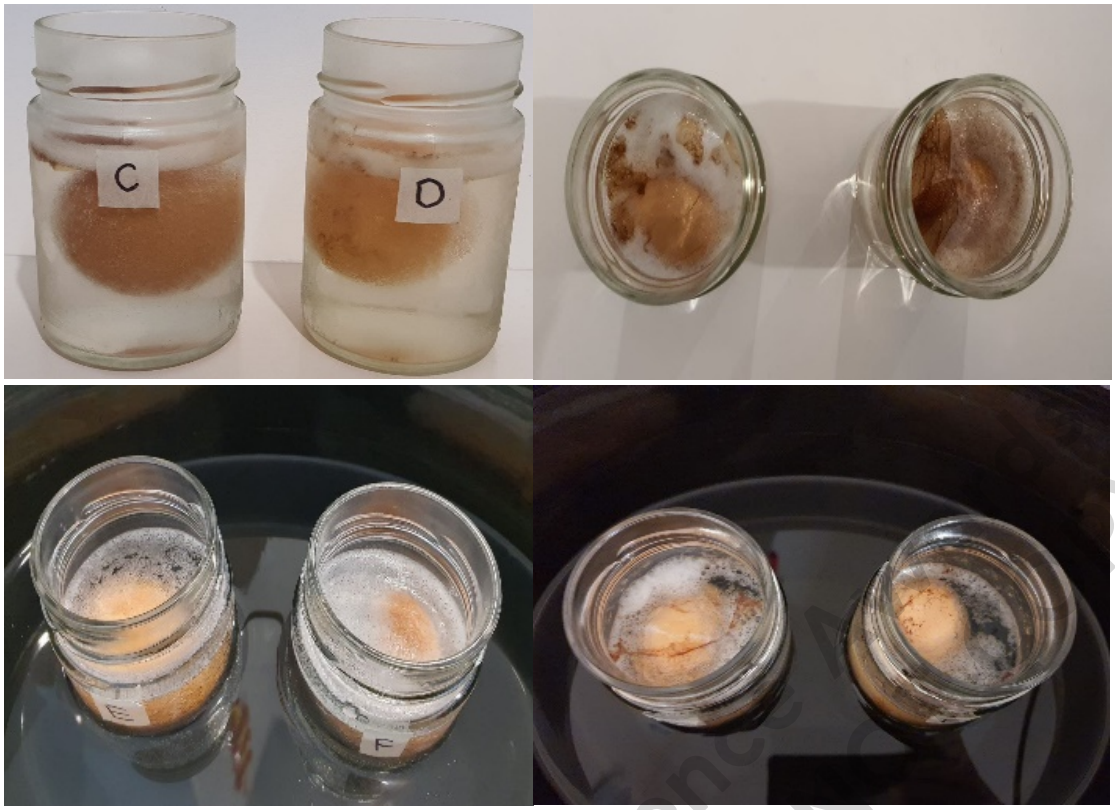
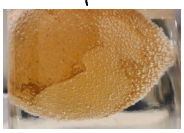


Figure 2. The photos of eggshells A to F under observation

Room Temperature

Table 3.1. Data observation at room temperature

Duration	Temperature	A	B
Immediate reaction, 0 to 15 mins	14 °C	The reaction starts with bubbling, fizzing and producing more bubbles. This phenomenon is effervescence.	Eggshell B has a faster and stronger reaction. It bubbles more indicating more CO2 being released.
15 mins	14 °C	Bubbling continues and starts to produce white foam (calcium acetate).	Eggshell B shows a faster reaction in producing bubbles (CO2) and white foam (calcium acetate).
1 hr 30 mins	13 °C	Its brownish cuticle starts to peel off.	Lots of its cuticle is peeling off. 

3 hrs	12 °C	Lots of white foam (calcium acetate).	Lots of white foam (calcium acetate).
4 hrs 30 mins	11 °C	More cuticle floats upon the surface	A layer of cuticle floats up on the surface. 
23 hrs	12 °C	More white foam is seen.	More white foam is seen. 
1 day 2 hr	13 °C	More white foam is seen.	More white foam is seen.
1 day 4 hrs	12 °C	More white foam is seen.	More white foam is seen.
1 day 8 hrs	8 °C	Less foamy.	Less foamy.
2 days	16 °C	Less foamy.	Less foamy.
2 days 1 hr	17 °C	Less foamy.	Less foamy.
2 days 5 hrs	13 °C	A little of its eggshell has dissolved.	A fifth of its eggshell has dissolved.
2 days 6 hrs	13 °C	Saw a little of the yolk.	Saw some parts of the yolk.
2 days 9 hrs	13 °C	Unobvious crack lines appear on the remaining eggshell and some parts of the eggshell dissolve.	White cracks appear on the remaining eggshell and the golden yolk is seen.
3 days 5 hrs	15 °C	More white crack lines have appeared. 	Half of the eggshell has dissolved, and more parts of the golden yolk is seen.
3 days 23 hrs	13 °C	Increased white crack lines are seen.	Five eighths of the eggshell have dissolved.
6 days 3 hrs	-	Increased white crack lines are seen.	Three fourths of the eggshell have dissolved.
8 days 21 hrs	-	Increased white crack lines are seen.	Fully dissolved.
9 days 10 hrs	-	Fully dissolved. 	-

Low Temperature

Table 3.2. Data observation at low temperature

Duration	Temperature	C	D
0 -10 mins	-	Bubbling / effervescing.	Lots of bubbles.
10 mins	3.3 °C	Slowly bubbling.	Slowly bubbling.
1 hr	-	The egg stays vertical.	The egg has turned to horizontal.
11 hrs	2.8 °C	Calcium acetate (white foam) appears.	D has more calcium acetate (white foam) than C.
13 hrs	-	More bubbles surround the egg.	More bubbles surround the egg.
17 hrs	2.3 °C	Parts of its cuticle come off the eggshell and floats on the surface. White foam (calcium acetate) has increased.	Eggshell D's cuticle comes off and floats on the surface. D has more white foam floats than C.
20 hrs	-	Effervescing.	Effervescing
22 hrs	3.3 °C	C has more cuticles coming off the egg and floats than D.	More parts of the cuticle come off the eggshell and floats on the surface.
24 hrs	3.4 °C	More parts of the cuticle come off the eggshell and floats on the surface.	More parts of the cuticle come off the eggshell and floats on the surface.
1 day 14 hrs	2.3 °C	C has more cuticles and foam floating up than D.	Increased peeling of the cuticle is observed.
1 day 17 hrs	2.8 °C	Foamy.	Foamy.
1 day 20 hrs	3.5 °C	Foamier.	Foamier.
3 days	-	A bit of yolk is seen	The whole yolk is seen because the eggshell is very thin.

3 days 20 hrs	-	Very small patches of eggshell have dissolved.	A fifth of the eggshell has dissolved.
4 days 16 hrs	2.3 °C	The eggshell is slowly dissolving.	A fourth of the eggshell has dissolved. Eggshell D dissolves more than Eggshell C.
6 days 18 hrs	2.7 °C	A little bit more eggshell has dissolved.	Big patches of eggshell have dissolved.
11 days 12 hrs	3.4 °C	Nearly dissolved.	Fully dissolved.
11 days 23 hrs	2.8 °C	Fully dissolved. 	

High Temperature

Table 3.3. Data observation at high temperature

Duration	Temperature	E	F
0 – 10 mins	-	Effervescence takes place.	Effervescence takes place in F earlier and faster than in E.
10 mins	58.6 °C	More bubbling and foam of calcium acetate are produced.	Obviously, more bubbles and foam are produced in F than in E.
1 hr 30 mins	61 °C	More foam is seen. Parts of its cuticle floats on the surface.	Lots of foam is observed. Some parts of its cuticle float on the surface.
3 hrs	69.5 °C	Foam has increased.	Foam has increased.
4 hrs	58.3 °C	Foamy.	Foamy.

9 hrs	54.1 °C	The slow cooker stinks with the strong smell of vinegar.	The slow cooker stinks with the strong smell of vinegar, indicating that some of the vinegar vapourise.
10 hrs	53.7 °C	The eggshell shows irregular crack lines.	The eggshell shows irregular crack lines.
23 hrs	70.3 °C	Its vinegar solution has decreased due to evaporation. Less foamy.	Its vinegar solution has decreased due to evaporation. Less foamy.
1 day 8 hrs	50.9 °C	White deposits of calcium acetate adhere to the inside glass. More vinegar has evaporated, and less foamy.	White deposits of calcium acetate adhere to the inside glass. More vinegar has evaporated, and less foamy.
1 day 10 hrs	68.5 °C	The cooked egg is visible because the eggshell becomes thinner.	The cooked egg is visible because the eggshell becomes thinner.
2 days	71.6 °C	Vinegar level has decreased. Less foamy.	Vinegar level has decreased. Less foamy.
2 days 1 hr	56.7 °C	More white deposits of calcium acetate adhering to the inner glass.	F has more white deposits adhering to the inner glass than E.
2 days 8 hrs	-	Some white crack lines appeare on the egg.	F has more white crack lines on the egg than E had.
3 days 4 hrs	-	E has less eggshell dissolved than F.	Two thirds of the eggshell have dissolved.
3 days 23 hrs	-	More of the eggshell dissolved.	More of the eggshell dissolved.
4 days	-	Vinegar level has decreased below the egg. Three fourths of eggshell dissolved.	Vinegar level has decreased below the egg. Four fifths of eggshell dissolved.
4 days 10 hrs	-	Nearly dissolved.	Fully dissolved.
4 days 23 hrs	-	Fully Dissolved.	-

Figure 3. The graph of the temperature and concentration of the vinegar versus time taken for the eggshell to be dissolved

The order of the rate of reaction

The rate of reaction for the eggshell to be dissolved for different temperature and concentration is compared (Figure 3, Table 4). When eggshell encounters with vinegar, the calcium and carbonate ions are more firmly linked to the acetic acid molecules than they are together. Eggshell F becomes the first to dissolve because its vinegar concentration is higher and placed at high temperature. When vinegar concentration is higher, more acetic acid molecules pull apart the calcium and carbonate ions. At high temperature, molecules receive heat energy, so they are agitated to move faster. In contrast, eggshell C become the slowest to dissolve because it is placed at a low temperature causing the molecules to move slower, and with its lower vinegar concentration, less acetic acid molecules bond with calcium ions at a given time.

Table 4. The order of the rate of reaction for the eggshell to be dissolved

Order	Label	Duration
1	F	4 days 10 hrs (106 hrs)
2	E	4 days 23 hrs (119 hrs)
3	B	8 days 21 hrs (213 hrs)
4	A	9 days 10 hrs (226 hrs)
5	D	11 days 12 hrs (276 hrs)
6	C	11 days 23 hrs (287 hrs)

The result shows that, for the group of 4% concentrated vinegar, eggshell E dissolves faster than eggshell A, followed by eggshell C. Whereas, for the group of 8% concentrated vinegar, eggshell F dissolves faster than eggshell B, followed by eggshell D. This indicates that eggshells dissolve the fastest at high temperature than the room temperature, followed by the low temperature at a given concentration of vinegar (Table 5). This supports the hypothesis that higher temperature increases the chemical reaction.

Table 5. The rate of reaction is compared at three temperature settings.

Order of the rate of reaction	4% Concentrated vinegar	8% Concentrated vinegar
1 (50.9 °C – 72.3 °C)	E	F
2 (8 °C – 17 °C)	A	B
3 (2.3 °C – 3.5 °C)	C	D

The order of the rate of reaction is affected by

High Temperature > Room Temperature > Low temperature

The data also shows that, for the three temperature groups, eggshell B dissolves faster than eggshell A, eggshell D dissolves faster than eggshell C, and eggshell F dissolves faster than eggshell E. (Table 6). This implies that more concentrated acetic acid (8%) dissolves an eggshell faster than less concentrated acetic acid (4%) at a given temperature setting. This supports the hypothesis that higher concentration increases the chemical reaction.

Table 6. The rate of reaction is compared at two concentrations of acetic acid.

Order of the rate of reaction	Room Temperature (8 °C – 17 °C)	Low Temperature (2.3 °C – 3.5 °C)	High Temperature (50.9 °C – 72.3 °C)
1	B	D	F
2	A	C	E

The order of the rate of reaction is affected by

Higher Concentration > Lower Concentration

Overall, eggshells F and E dissolves faster than eggshells B and A, followed by eggshell D and C. This happens because the three temperature settings used in this experiment have a large difference while the two different concentrations of vinegar have a little difference.

Comparing the deshelled eggs

The naked eggs are soft and bouncy, and have a strong smell of vinegar. They are generally swollen, larger and heavier than their initial size due to osmosis. The deshelled eggs A, C and D are 33 to 55% heavier than their initial weight (Table 7, Figure 4).

Table 7. The weight change of the naked eggs

Deshelled eggs	Final weight (g)	Increase in weight (%)
A	86	43
C	93	55
D	80	33

A C D Normal EGG

The calculation to find the increase of weight in percentage:

$$\text{Increase of weight (percentage)} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100$$

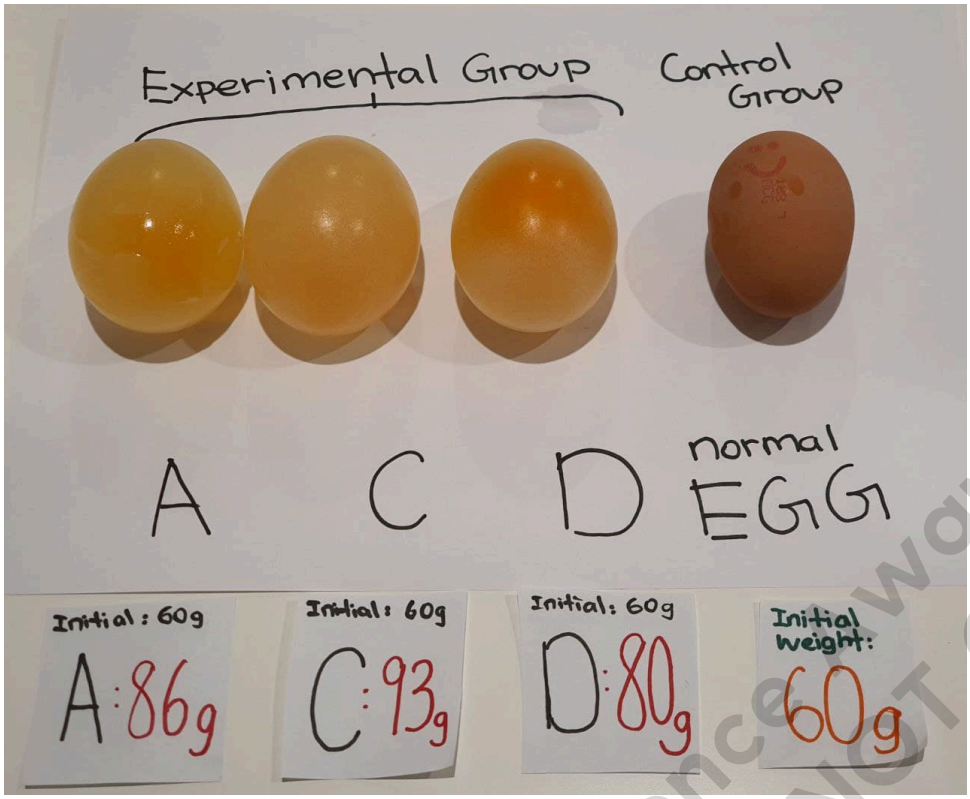


Figure 4.1. The deshelled eggs A, C and D

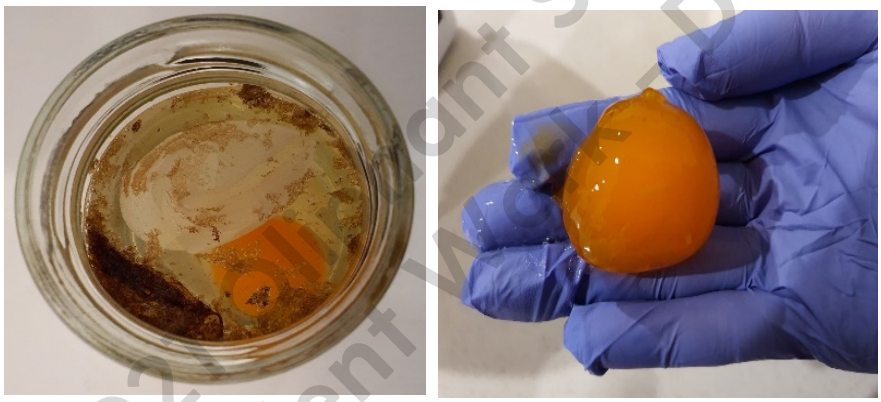


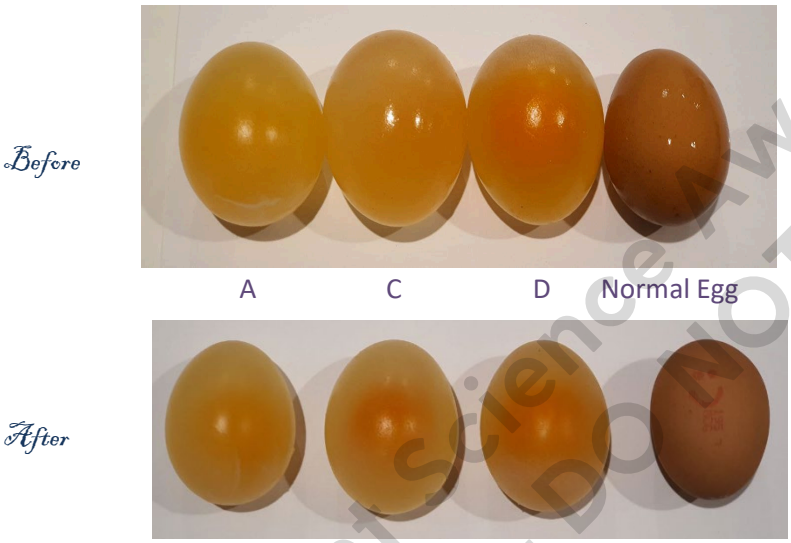
Figure 4.2. The deshelled eggs B with its egg yolk, egg white, cuticle and shell membrane

Figure 4.3. The deshelled eggs E and F which are cooked

While being placed at room temperature, the naked eggs are shrinking slowly. Three days later, they are smaller and 7.5 to 16% lighter than their initial weight due to osmosis (Table 8, Figure 5).

Table 8. The weight change of the naked eggs 3 days after being placed at room temperature.

Deshelled eggs	Initial weight (g)	Decrease in weight (g)	Weight change (%)
A	86	72	-16
C	93	79	-15
D	80	74	-7.5



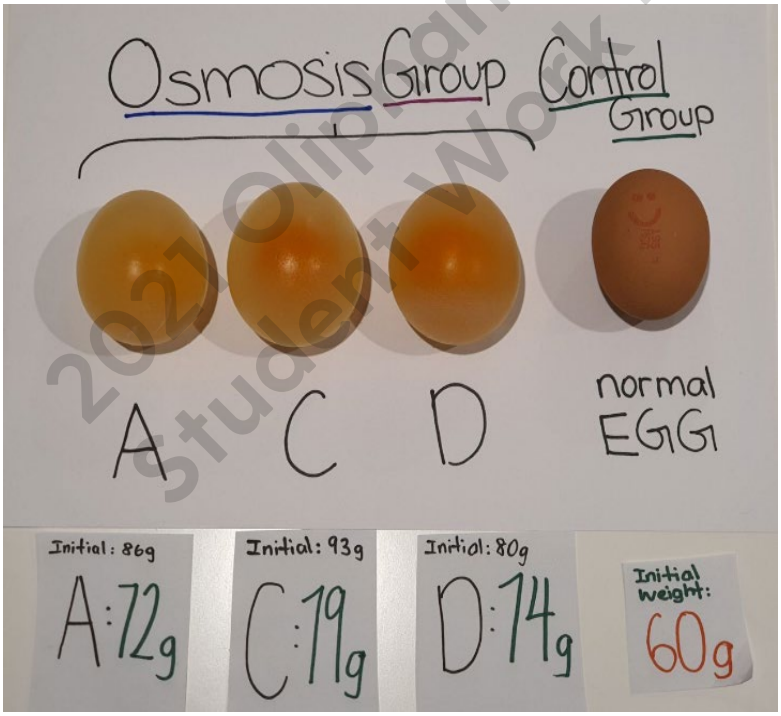


Figure 5. The weight of the naked eggs has reduced 3 days after being placed at room temperature.

Discussion and Evaluation

Usefulness of this experiment and extension of knowledge

Tooth enamel, the outer layer of the teeth which is made of calcium phosphate, may dissolve in acid. When the tooth encounters with acid, calcium and phosphate ions are pulled apart to bind with acetic acid molecules to form calcium acetate. If the PH of the solution in the mouth is very low which means very acidic, the teeth can dissolve to form cavity. Alike to the egg in vinegar, the higher the concentration is, the faster and the more amount the tooth dissolve. Sugar from soda or soft drinks interacts with the bacteria to produce acid which may damage our teeth. It is reported that drinking excessive soft drinks can lead to erosion, cavity and tooth decay. However, our teeth will not dissolve when consuming acidic liquid because saliva contains sodium bicarbonate which neutralises the acids and prevents our teeth from dissolving. It is noteworthy to be aware of the damaging effects of acidic food or drink to the tooth enamel when there is saliva deficiency.

Chicken bones are made of calcium carbonate and collagen. When chicken bone is placed in vinegar, the acetic acid can dissolve the calcium carbonate, leaving the collagen to be bendy. However, food and drinks containing acid do not dissolve human bones. It is important to ensure nourishments containing sufficient calcium such as milk, dairy products and so on, are consumed frequently to build and maintain our bones to be strong and healthy as calcium is not produced in our body; it is all rely on our dietary intake.

When something happens to our cells such as injuries, inflammation, disease, our cells can be swollen like the naked eggs in this experiment. Similar to shell membrane, cell membrane is semipermeable. Osmosis is the process of water molecules passing through the semipermeable membrane by diffusion from one side of higher concentration to the other side of lower concentration. This experiment shows how osmosis takes place through semipermeable membrane to make the naked eggs swell or shrink. Therefore, maintaining dynamic equilibrium for the cell environment is vital to keep us healthy.

Calcium acetate is used as a medication to control the blood level of phosphate for patients who have severe kidney disease. It is usually consumed with food in the form of capsule, tablet and solution. It is essential to take the correct dosage according to doctor's prescription. Some common side effects of calcium acetate include nausea, vomiting, stomach upset and so on.

A little tip can save a lot of time when preparing boiled eggs! Vinegar can soften the eggshells. Therefore, a bit of vinegar can be added in the pot of boiling water with eggs so that it is easier to peel off the eggshells. Another example of the eggs undergoing osmosis is the soy-flavoured iron egg which is a popular snack in Taiwan.

Control trial

As only acid can dissolve eggshells, so control trial was not done in this experiment.

Random Error

Opening the slow cooker's glass lid makes the vinegar evaporates faster and therefore the vinegar level drops.

Systematic Error

Systematic error is minimised if all equipment is functioning with accurate reading.

Limitations

A limitation in this experiment is that the decreased vinegar level of eggshells E and F may cause the eggshell to dissolve at a slower rate.

Improvement

The future experiment can be improved by utilising apparatus with a thermostat that keeps a preset temperature constant and using a higher concentration of acetic acid may give a more significant result.

Conclusion

The experiment supports the hypotheses that eggshell dissolves faster in vinegar at higher temperature than lower temperature, and eggshell dissolves faster in more concentrated vinegar than less concentrated vinegar. Such chemical reactions are influenced by the concentration of the acid and base as well as the ambient temperature. Without shells, the naked eggs are able to maintain their shape because of the shell membrane. The deshelled eggs experience a change in size and weight due to the effect of osmosis through semipermeable membrane.

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Science Journal

Chloe Yaan Yuit Yew

Notes and Research

Title

The Rate of Reaction of the Calcium Carbonate Dissolving in Acetic Acid

Research Question

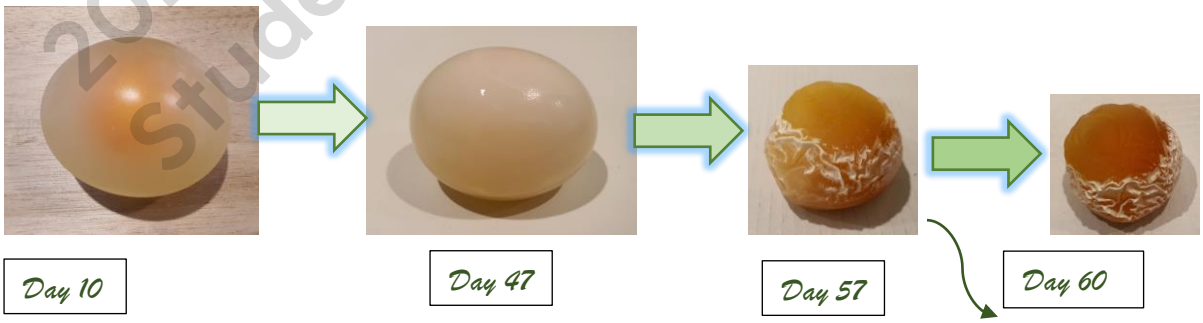
How fast will the eggshell dissolve in vinegar at three different temperatures and at two different concentrations of vinegar?

10/3/2021 - 10/5/2021

- *Working on a pilot study*
- *To observe the chemical reaction between an egg and vinegar solution*
- *Learning topic:*
  - *Acid and base*
  - *Diffusion, osmosis*

Obervation of the pilot study:

Figure. Observation of the acid base reaction



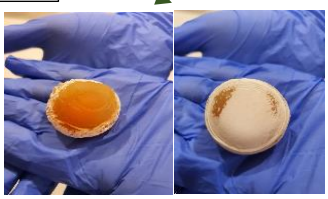


Figure. Observation of the osmosis effect in a deshelled egg
The naked egg shrinks over time.

10/5/2021 - 7/7/2021

- *Doing research online*
- *Going to library to look for available sources*
- *Discussion with Science teachers*
- *Brainstorming ideas with my brothers and mum*
- *Learn the structure of a scientific report*
- *To decide the focus of investigation and narrow down the topic*

27/6/2021 - 7/7/2021

Preliminary Study:

What is vinegar?

- Sour-tasting liquid produced through the fermentation of ethanol by acetic acid bacteria using wine, cider, or beer.
- Contains acetic acid, the chemical formula is CH_3COOH. PH = 2.5, molecular weight = 60g/mole.
- Health benefits: antimicrobial properties, fighting diabetes, improving dandruff, controlling blood sugar, and reducing belly fat and cholesterol.
- Used as cleaning agent and stain removal.
- Used as a dressing or a substitute for other ingredients.
- Outdoor uses: killing weeds, improving soil, detailing cars, and repelling mosquitos.
- A variety of vinegar: apple cider vinegar, white vinegar, balsamic vinegar, white wine vinegar, red wine vinegar, rice vinegar and malt vinegar.

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What is eggshell?

- A hard outer layer of an egg. What is its structure? What holds the egg shape when it is deshelled?
- Made of calcium carbonate (CaCO3)
- Brittle, prevent bacteria from getting in.

References:

The eggshell: structure, composition and mineralization (2021). Available at: https://www.researchgate.net/publication/51895246

What is acid base reaction?

- When a raw egg is placed in white vinegar, the eggshell will dissolve. Why?
- When calcium carbonate reacts with acetic acid, the end products are calcium acetate, water and carbon dioxide gas. Why?
- Chemical equation:

$2\ CH_3COOH_{(aqueous)} + CaCO_{3\ (solid)} \Rightarrow Ca(CH_3COO)_{2\ (solid)} + H_2O_{(aqueous)} + CO_{2\ (gas)}$

Acetic acid + Calcium carbonate ⇨ Calcium acetate + Water + Carbon dioxide

References:

1. *https://www.indypl.org/blog/for-kids/science-experiment-acids-bouncing-egg*
2. *https://www.factmonster.com/cig/science-fair-projects/making-eggs-bounce*
3. *https://www.stevespanglerscience.com/lab/experiments/naked-egg-experiment/*
4. *https://www.scienceofcooking.com/eggs/naked-egg-experiment.html*

Aim

To investigates the rate of reaction of an eggshell dissolving at three different temperatures (room temperature, low temperature, and high temperature), and at two different concentrations of the acetic acid (4% and 8%)

- What factors affect how fast eggshell will be dissolved?
- What will I learn from this experiment?
- What will this experiment be extended to other similar situation such as when bone or teeth encountering acids?
- What happens to the deshelled eggs?

Hypothesis

1. The higher the temperature is, the faster the eggshell dissolves in vinegar
2. The higher the concentration of the vinegar is, the faster the eggshell dissolves in vinegar

Reference:

https://www.doe.virginia.gov/testing/sol/standards_docs/science/2010/lesson_plans/grade1/matter/sess_1-3c.pdf

Variables

Independent Variables

- The temperature and the concentration of the vinegar

Dependent Variables

- The time taken for the eggshell to dissolve in vinegar

Controlled Variables

Controlled Variables are to ensure that this experiment is a 'fair test' (Table).

Table. Controlled Variables

Controlled Variables	Method of Control	Effects on the Experiment
The amount of vinegar for each glass	• Same weight = 180g • Weighed by a digital scale	• Different amount of vinegar dissolves the eggshell at a different rate.
The size of each glass	• Identical size • Same brand	• Glasses are inert to vinegar. • Identical size to ensure that the liquid level is the same.
The weight of the eggs	• Same weight = 60g • Weighed by a digital scale	• Same weight to ensure the total surface area of the eggshell is the same. • Increased total surface of the eggshell may increase the rate of reaction. • The thickness of the eggshell should be considered.

Uncontrolled Variables

- Now is winter, the room temperature is low, expected slower rate of reaction than in summer.
- The room temperature is not controlled and varies daily: affect the time taken for the eggshell to dissolve.
- No intention to conduct this experiment at a fixed temperature, and therefore expected a varied range of temperature.

7/7/2021 - 19/7/2021

Conducting experiment

Equipment and Materials

1. 6 raw eggs of the same weight (60g)



2. White vinegar
   - What is the concentration of vinegar available in the market?

     4% and 8% concentration of acetic acid
3. 6 glasses of the same size

4. Thermometer (Range of temperature -50°C – 300 °C)
5. Digital scale
6. Fridge
7. Slow cooker (warm setting)

Procedure:

1. Make sure each glass is dry and rinse each glass with vinegar to prevent dilution.

2. Fill each glass with 180g white vinegar.

3. Place 6 raw eggs in each glass carefully.
4. Label each glass appropriately. (Table)
5. Place the six glasses with the eggs at three different temperature settings (room temperature, low temperature and high temperature).
6. Record the temperature using thermometer.

Table. The eggshells are labelled.

Label	Temperature	Concentration of Vinegar
A	room temperature (8 °C – 17 °C)	4%
B	room temperature (8 °C – 17 °C)	8%
C	low temperature (2.3 °C – 3.5 °C)	4%
D	low temperature (2.3 °C – 3.5 °C)	8%
E	high temperature (50.9 °C – 72.3 °C)	4%
F	high temperature (50.9 °C – 72.3 °C)	8%

Risk Assessment

1. Chemical risks:
   - Chemical contacts were avoided by putting on an apron, gloves, and safety goggles.
   - The glasses were handled with care to prevent spilling.
   - Any spilled substances were cleaned and removed instantly.
2. Thermal risks:
   - The glasses were carefully placed in the slow cooker to prevent scalds from hot water.
3. Electrical risks:
   - The slow cooker was inspected for electrical safety.
   - Hands were dried before turning on the switch to reduce the risk of electrical hazards.
4. Handling risks:
   - All equipment including the digital scale was kept dry and clean.
   - The digital scale and thermometer were examined for any damage.
5. Environmental Considerations: any hazard or danger to the environment?
6. Ethical Considerations: Are raw eggs considered living things?

Reference:

https://www.raising-happy-chickens.com/fertile-chicken-eggs.html

Processing and Analysing Data and information

Data Observation

The key observation for this experiment:
The acid-base reaction between the acetic acid and the calcium carbonate which produces calcium acetate, water scarbon dioxide gas was observed. (Table)

Photos:

Figure. The photos of eggshells A to F under observation

Room Temperature

Table. Data observation at room temperature

Time	Duration	Temperature	A	B
8.7.21, 1:30 pm	Immediate reaction, 0 to 15 mins	14 °C	The reaction starts with bubbling and producing more bubbles.	Faster and stronger reaction. It bubbles more to release gas.
8.7.21, 1:45 pm	15 mins	14 °C	Bubbling continues and white foam (calcium acetate) starts to produce.	Faster reaction in producing bubbles (CO_2) and white foam (calcium acetate).
8.7.21, 3:00 pm	1 hr 30 mins	13 °C	Its cuticle starts to peel off.	Lots of its cuticle is peeling off.
8.7.21, 4:30 pm	3 hrs	12 °C	Lots of white foam (calcium acetate).	Lots of white foam (calcium acetate).
8.7.21, 6:00 pm	4 hrs 30 mins	11 °C	More cuticle floats up on the surface	A layer of cuticle floats up on the surface.
9.7.21, 12:30 pm	23 hrs	12 °C	More white foam is seen.	More white foam is seen.
9.7.21, 3:30 pm	1 day 2 hr	13 °C	More white foam is seen.	More white foam is seen.
9.7.21, 5 ;30 pm	1 day 4 hrs	12 °C	More white foam is seen.	More white foam is seen.
9.7.21, 9:30 pm	1 day 8 hrs	8 °C	Less foamy.	Less foamy.
10.7.21, 1:30 pm	2 days	16 °C	Less foamy.	Less foamy.

10.7.21, 2:30 pm	2 days 1 hr	17 °C	Less foamy.	Less foamy.
10.7.21, 6:30 pm	2 days 5 hrs	13 °C	A little of its eggshell has dissolved.	A fifth of its eggshell has dissolved.
10.7.21, 7:30 pm	2 days 6 hrs	13 °C	Saw a little of the yolk.	Saw some parts of the yolk.
10.7.21, 10:30 pm	2 days 9 hrs	13 °C	Unobvious crack lines appear on the remaining eggshell and some parts of the eggshell dissolve.	White cracks appear on the remaining eggshell and the golden yolk is seen.
11.7.21, 6:30 pm	3 days 5 hrs	15 °C	More white crack lines have appeared.	Half of the eggshell has dissolved, and more parts of the golden yolk is seen.
12.7.21, 12:30 pm	3 days 23 hrs	13 °C	Increased white crack lines are seen.	Five eighths of the eggshell have dissolved.
14.7.21, 4:30 pm	6 days 3 hrs	-	Increased white crack lines are seen.	Three fourths of the eggshell have dissolved.
17.7.21, 10:30 am	8 days 21 hrs	-	Increased white crack lines are seen.	Fully dissolved.
17.7.21, 11:30 pm	9 days 10 hrs	-	Fully dissolved.	-

Low Temperature

Table. Data observation at low temperature

Time	Duration	Temperature	C	D
7.7.21, 10:00 pm	0 -10 mins	-	Bubbling.	Lots of bubbles.
7.7.21, 10:10 pm	10 mins	3.3 °C	Slowly bubbling.	Slowly bubbling.
7.7.21, 11:00 pm	1 hr	-	The egg stays vertical.	The egg has turned to horizontal.
8.7.21, 9:00 am	11 hrs	2.8 °C	Calcium acetate (white foam) appears.	D has more calcium acetate (white foam) than C.
8.7.21, 11:00 am	13 hrs	-	More bubbles surround the egg.	More bubbles surround the egg.
8.7.21, 3:00 pm	17 hrs	2.3 °C	Parts of its cuticle come off the eggshell and floats on the surface. White foam (calcium acetate) has increased.	Its cuticle comes off and floats on the surface. D has more white foam floats than C.
8.7.21, 6:00 pm	20 hrs	-	Effervescing.	Effervescing.
8.7.21, 8:00 pm	22 hrs	3.3 °C	C has more cuticle coming off the egg and floats than D.	More parts of the cuticle come off the eggshell and floats on the surface.
8.7.21, 10:00 pm	24 hrs	3.4 °C	More parts of the cuticle come off the eggshell and floats	More parts of the cuticle come off the eggshell and floats

			on the surface.	on the surface.
9.7.21, 12:00 pm	1 day 14 hrs	2.3 °C	C has more cuticles and foam floating up than D.	Increased peeling of the cuticle.
9.7.21, 3:00 pm	1 day 17 hrs	2.8 °C	Foamy.	Foamy.
9.7.21, 6:00 pm	1 day 20 hrs	3.5 °C	Foamier.	Foamier.
10.7.21, 10:00 pm	3 days	-	A bit of yolk is seen	The whole yolk is seen. The eggshell is very thin.
11.7.21, 6:00 pm	3 days 20 hrs	-	Very small patches of eggshell have dissolved.	A fifth of the eggshell has dissolved.
12.7.21, 2:00 pm	4 days 16 hrs	2.3 °C	The eggshell is slowly dissolving.	A fourth of the eggshell has dissolved. Eggshell D dissolves more than Eggshell C.
14.7.21, 4:00 pm	6 days 18 hrs	-	A little bit more eggshell has dissolved.	Big patches of eggshell have dissolved.
19.7.21, 10:00 am	11 days 12 hrs	-	Nearly dissolved.	Fully dissolved.
19.7.21, 9:00 pm	11 days 23 hrs	-	Fully dissolved.	-

High Temperature

Table. Data observation at high temperature

Time	Duration	Temperature	E	F
8.7.21, 1:30 pm	0 – 10 mins	-	Effervescence takes place.	Effervescence takes place in F earlier and faster than in E.
8.7.21, 1:40 pm	10 mins	58.6 °C	More bubbling and foams of calcium acetate are produced.	More bubbles and foams are produced in F than in E.
8.7.21, 3:00 pm	1 hr 30 mins	61 °C	More foam is seen. Parts of its cuticle floats on the surface.	Lots of foam is observed. Some parts of its cuticle float on the surface.
8.7.21, 4:30 pm	3 hrs	69.5 °C	Foam has increased.	Foam has increased.
8.7.21, 5:30 pm	4 hrs	58.3 °C	Foamy.	Foamy.
8.7.21, 10:30 pm	9 hrs	54.1 °C	The slow cooker stinks with the strong smell of vinegar.	The slow cooker stinks with the strong smell of vinegar.
8.7.21, 11:30 pm	10 hrs	53.7 °C	The eggshell shows irregular crack lines.	The eggshell shows irregular crack lines.
9.7.21, 12:30 pm	23 hrs	70.3 °C	Its vinegar solution has decreased. Less foamy.	Its vinegar solution has decreased due to evaporation. Less foamy.
9.7.21, 12:30 pm	23 hrs	50.9 °C	White deposits of calcium acetate adhere to the inside	White deposits of calcium acetate adhere to the inside

			glass. More vinegar has evaporated, and less foamy.	glass. More vinegar has evaporated, and less foamy.
9.7.21, 9:30 pm	1 day 8 hrs	68.5 °C	The cooked egg is visible because the eggshell becomes thinner.	The cooked egg is visible because the eggshell becomes thinner.
9.7.21, 11:30 pm	1 day 10 hrs	71.6 °C	Vinegar level has decreased. Less foamy.	Vinegar level has decreased. Less foamy.
10.7.21, 1:30 pm	2 days	56.7 °C	More white deposits of calcium acetate adhering to the inner glass.	F has more white deposits adhering to the inner glass than E.
10.7.21, 9:30 pm	2 days 8 hrs	-	Some white crack lines appeared on the egg.	F has more white crack lines on the egg than E had.
11.7.21, 5:30 pm	3 days 4 hrs	-	E has less eggshell dissolved than F.	Two thirds of the eggshell have dissolved.
12.7.21, 12:30 pm	3 days 23 hrs	-	More of the eggshell dissolved.	More of the eggshell dissolved.
12.7.21, 1:30 pm	4 days	-	Vinegar level has decreased below the egg. Three fourths of eggshell dissolved.	Vinegar level has decreased below the egg. Four fifths of eggshell dissolved.
12.7.21, 11:30 pm	4 days 10 hrs	-	Nearly dissolved.	Fully dissolved.
13.7.21, 12:30 pm	4 days 23 hrs	-	Fully Dissolved.	-

Learning:

- To design a graph of the temperature and concentration of the vinegar versus time taken for the eggshell to be dissolved.
- Showing the results using bar and line graphs
- To detect any differences between temperature and concentration groups

Thinking Process:

The order of the rate of reaction

Questions:

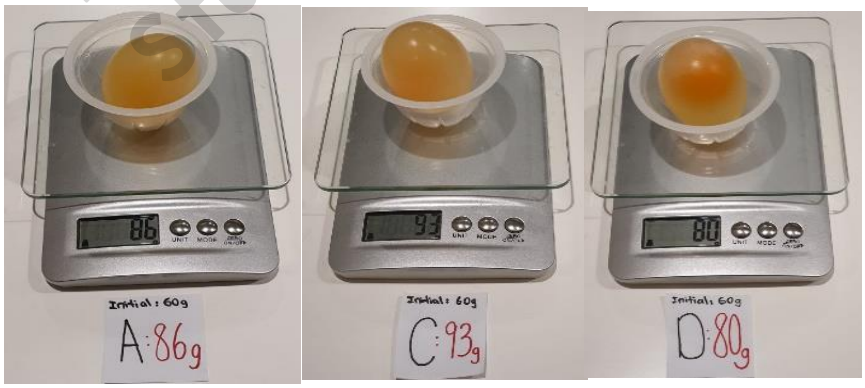
- Compare the rate of reaction for the eggshell to be dissolved for different temperature and concentration. Who is the winner? Who is the slowest? Why?
- Is the result the same as expected? Why?
- To create a table to show the order of the rate of reaction for the eggshell to be dissolved.

Discuss the result findings:

- Compare the rate of reaction for three temperature settings. Why? Create a table.
- Compare the rate of reaction for two concentration settings. Why? Create a table.
- What is the effect with the combination of temperature and concentration?

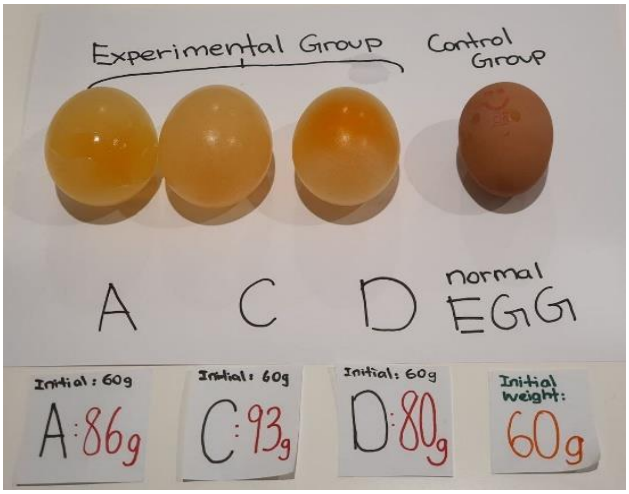
Final work: 19/7/2021

- Washing the naked eggs and weighing them. They are so cute, soft and bouncy!

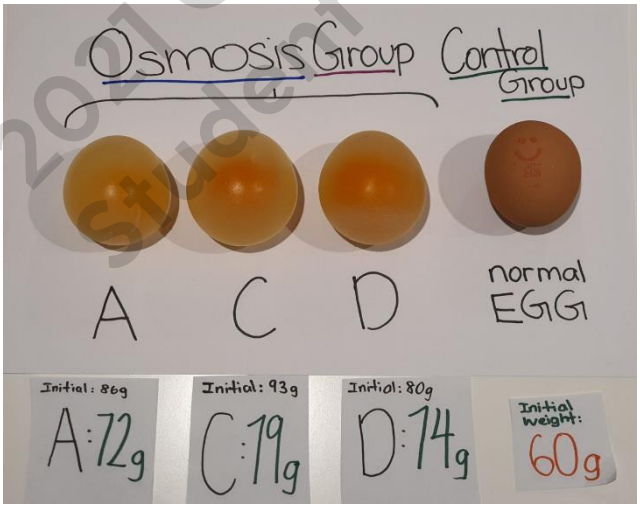


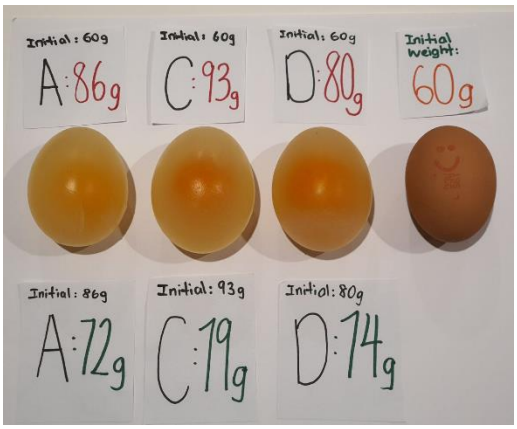
- The naked eggs are swollen and heavier than their initial weights. To find out more! Causes: Osmosis. Create a table to compare the weight gain.

  The increase of weight = $\frac{\text{Final weight – Initial weight}}{\text{Initial weight}} \times 100$ (percentage)



- What happens to the naked eggs 3 days later? ~~22/7/2021~~ Analyse the change. They are shrinking slowly. Caculate the weight change.





- Observe the naked egg B. Poke it and see what is inside:
  Liquid egg white and golden egg yolk!


- Observe the naked eggs E and F. They look like salted egg but smell like a vinegar!


Discussion of interesting topics

Will similar situation happen when teeth encounter with vinegar? Is it good to have acidic drink? The answer is no. What is the consequence? Tooth decay, cavity and erosion.

Reference:

https://www.healthline.com/health/dental-oral-health/what-does-soda-do-to-your-teeth

Will similar situation happen when bone encounters with vinegar? Any effect to our human bone?

Reference:

1. *https://orthoinfo.aaos.org/en/staying-healthy/calcium-nutrition-and-bone-health/*
2. *https://learning-center.homesciencetools.com/article/skeletons-and-bones-science-projects/*

Function of semipermeable membrane: Shell membrane vs cell membrane, effect of osmosis

Cooking boiled eggs with a little bit of vinegar. What is the advantage?

Evaluation

Think: Can I do better than this?

Strengths

- Are there any useful applications of this knowledge?
  1. Vinegar helps peeling off eggshells with ease, time saving
  2. Dental care, soft drinks causing tooth cavity, sugary foods producing acids, saliva deficiency causing tooth erosion

Reference:

1. *http://scienceline.ucsb.edu/getkey.php?key=1413*
2. *https://ethosorthodontics.com.au/blog/is-apple-cider-vinegar-harming-your-teeth/*

Random Error

- What causes inconsistent result?
  1. Opening the slow cooker's glass lid makes the vinegar evaporates faster.
  2. The liquid level in E and F drops, therefore the whole egg is not covered by vinegar.

Systematic Error

- Think about any systematic error in this experiment.
  1. Equipment must be functioning properly.
  2. Measurements have to be accurate.

Limitations

- Any limitation due to the design of this experiment?
- Evaporation causes vinegar level of E and F to decrease.

Improvement

- What can I do to eliminate the limitation?
  1. Utilising apparatus that have a thermostat which keeps a set temperature constant.
  2. Using higher concentration of acetic acid, e.g. 20%, 40% to see any differences.

Conclusion:

- Does the experiment support the hypotheses?
- Two factors which affect the rate of reaction: temperature and concentration of vinegar
- Osmosis takes place through the shell membrane.

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8. Science Projects: Making Eggs That Bounce (2021). Available at: https://www.factmonster.com/cig/science-fair-projects/making-eggs-bounce (Accessed: July 2021).
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10. What Is Vinegar and How Is It Made? (2021). Available at: https://www.thespruceeats.com/what-is-vinegar-1328647 (Accessed: July 2021).
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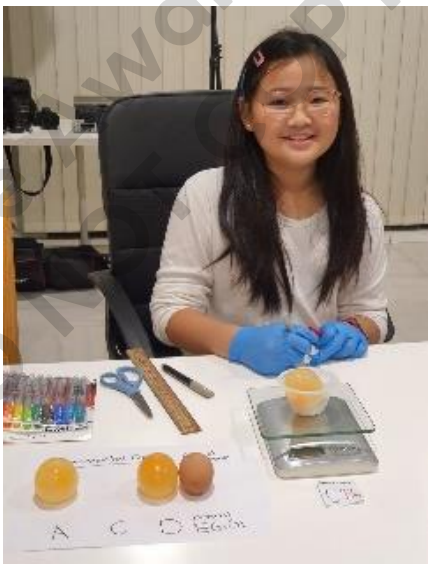
Assistance & Acknowledgement

While doing my research on understanding the chemistry behind the acid-base reaction, I also learned difficult scientific terms and how to do a scientific report. I asked questions and discussed my ideas with my family when I faced difficulties. I also improved my computer skills through learning from my brothers and my mum. I asked my parents to supply the materials for the experiment. I also asked my mother to assist me in taking photos for the project. My mother helped me to proofread my writing and report.



The END!

Chloe Yew

23.7.2021