



**Prize Winner**

**Science Investigation**

**Year 9 - 10**

**Simasiku Sepo**

**Walford Anglican School for  
Girls**





# ENAMEL UNDER ATTACK:

HOW POPULAR DRINKS  
ARE DESTROYING  
YOUR ENAMEL

**By: Sepo Simasiku**





# INTRODUCTION AND BACKGROUND

## **INTRODUCTION**

Oral hygiene is an essential component of general wellbeing, however oral infections remain among the most common and frequent global health conditions. According to a study by the World Health Organisation (2025), approximately 3.5 billion people suffer from oral diseases or infections, with untreated dental caries impacting roughly 2 billion adults. Along with tooth deterioration, dental erosion is an increasing concern as a result of an increase in consumption of acidic foods and beverages. Unlike dental caries, which are created from bacteria, dental erosion transpires from acids directly dissolving the minerals found within tooth enamel, resulting in irreversible damages (Lussi & Carvalho, 2014).

Contemporary diets constantly contain soft drinks, sports drinks, coffee and other acidic beverages, which have been associated with rapid rates of enamel erosion (Tahmassebi et al., 2006). Studies show that enamel begins to demineralise when exposed to pH levels below approximately 5.5 (Shellis et al., 2011). Considering that enamel is not able to regenerate naturally, understanding the effects of commonly ingested liquids on enamel is vital for advancing oral health techniques. This investigation intends to explore how acidity influences the degree of erosion and staining monitored in hard-boiled eggshells used as a replica for human tooth enamel.



## **BACKGROUND INFORMATION**

Tooth enamel is the greatly mineralised external layer of the tooth and is formulated largely of hydroxyapatite crystals. Although enamel is the toughest substance in the human body, it is exposed to chemical attack when left defenceless to acidic substances. Figure 1 demonstrates the configuration of a human tooth, displaying the location of enamel and its protective role. When acids are lower than the pH value of approximately 5.5, minerals are misplaced from the enamel surface, causing demineralisation and increasing susceptibility to deterioration (Shellis et al., 2011).

Acidity is measured using the pH scale, which ranges from 0 to 14, with lower values indicating greater acidity. Common beverages such as Coca-Cola and sports drinks have pH values varying from approximately 2.3 to 4.0, significantly beneath the critical pH enamel can endure (Tahmassebi et al., 2006). Figure 2 displays the pH scale.

## **RESEARCH QUESTION**

How does the acidity of various liquids determine the degree of damage produced on eggshells used as a replica for human tooth enamel over a three-day period?

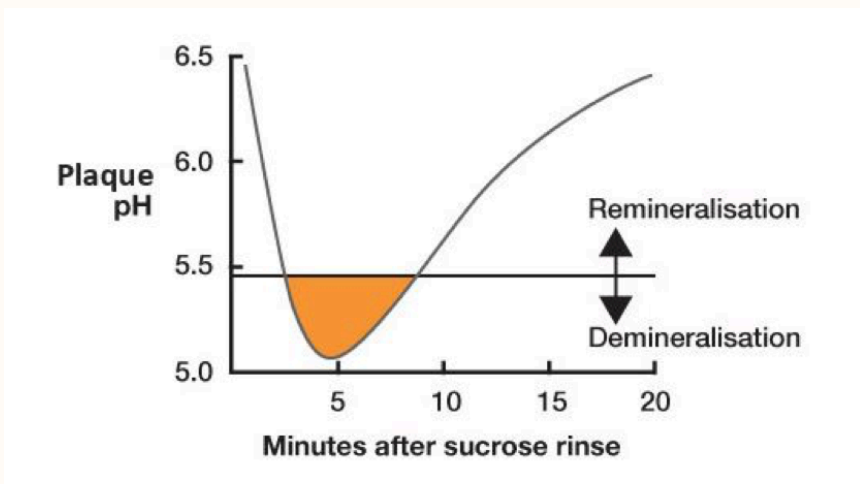
## **AIM**

The aim of this practical report is to discover how the pH and chemical composition of multiple liquids control the degree of erosion and discolouring seen on hard-boiled eggshells used as a model for tooth enamel. This will be accomplished by calculating the pH of each liquid and comparing changes in mass, colour, texture, and structure of the eggshells following three days of immersion. The experimental conclusions will then be compared with qualified, investigating the connection between acidity and enamel erosion.

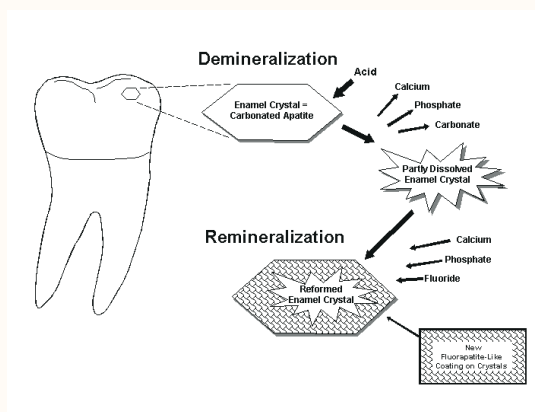
# QUESTIONING AND PREDICTING

## **BACKGROUND INFORMATION (continued)**

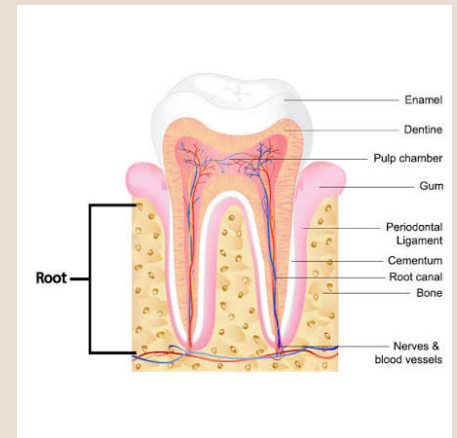
Due to ethical and moral restrictions connected with utilising human teeth, eggshells are generally applied as a substitute for tooth enamel. Eggshells consist of mostly calcium carbonate, which behaves with acids similarly to enamel. Consequently, changes in mass, colour and texture can be used to determine the effects of different liquids on mineralised surfaces (British Dental Journal, 2020). Figure 3 illustrates the processes of demineralisation and remineralisation in tooth enamel. Exposure to acidic substances creates the reduction of calcium and phosphate ions from enamel crystals, weakening the tooth structure. If the pH rises above the critical threshold, these minerals may be redeposited, allowing remineralisation to occur.



**Figure 2:** The Stephan curve illustrating the critical pH for enamel demineralisation. The graph shows the decrease and recovery of plaque pH following sugar exposure.



**Figure 3:** Demineralisation and remineralisation of tooth enamel. Acids increase the loss of calcium and phosphate ions from enamel crystals, resulting in demineralisation. When the oral environment becomes less acidic, these minerals can be redeposited, authorising remineralisation to occur.



**Figure 1:** Cross-sectional diagram displaying parts of the teeth including the enamel, dentine, pulp chamber, and root canal.

## **HYPOTHESIS**

It is hypothesised that liquids with lower pH values will cause greater erosion and staining of the eggshells due to their increased acidity. Therefore, vinegar is expected to cause the greatest degree of damage, while water is predicted to produce minimal changes and act as the control. An inverse relationship between pH and eggshell deserialisation is anticipated, with lower pH values, resultant in extensive levels of erosion.



# PLANNING AND CONDUCTING

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## **JUSTIFICATION OF EXPERIMENTAL DESIGN**

This method was chosen for this investigation because it provides a practical and ethical approach to examining the effects of acidic liquids on tooth enamel. Due to the difficulty and ethical concerns associated with using human teeth, hard-boiled eggshells were used as a substitute model, as both contain calcium-based minerals that undergo degradation when exposed to acidic environments. The use of eggshells also allowed visible changes in mass, colour, texture, and structural integrity to be observed over a relatively short period.

The investigation utilised six commonly consumed liquids with dissimilar pH levels to analyse the relationship between acidity and enamel erosion. Measuring the pH of each liquid prior to the experiment enabled the influence of acidity on eggshell degradation to be investigated. Three trials were performed for each liquid to enhance the reliability of the results and minimise the effect of anomalies. Furthermore equal volumes of liquid, and a constant exposure period ensured that experimental conditions remained controlled. This method is simple and easily replicable, allowing the relationship between pH and enamel erosion to be examined using both quantitative and qualitative data.

## **EXPERIMENTAL VALIDITY AND RELIABILITY**

To ensure that this investigation was conducted as a fair test, only one variable, the type of liquid, was intentionally varied, while all other variables that could influence the dependent variables were kept controlled. This enabled the effect of liquid acidity and composition on eggshell erosion to be isolated and investigated. To increase the reliability of the results, three eggs were used for each liquid and the average change in mass was calculated. In addition equal volumes of liquid, and a constant exposure period were used to maintain consistent experimental conditions. The same measuring equipment and pH testing method were used throughout the investigation to minimise systematic errors and preserve the accuracy and validity of the results.

## **INDEPENDANT VARIABLE**

The type of liquid used to immerse the eggshells (water, Coca-Cola, coffee, Gatorade, vinegar, and toothpaste solution).

## **DEPENDANT VARIABLE**

The change in eggshell mass, colour, texture, and visible erosion after three days of immersion.

## **CONTROLLED VARIABLES**

- Brand of eggs
- Volume of liquid
- Immersion time
- Temperature and environment
- Beaker type
- Preparation of eggs
- Measuring equipment
- Amount of submersion

# EQUIPMENT AND MATERIAL

## MATERIALS

- 20 hard-boiled eggs
- 18 beakers
- Water
- 450ml of CocaCola
- 450ml of Coffee
- 450ml of Gatorade
- 450ml of Vinegar
- 450ml of Toothpaste Solution
- pH strips
- Measuring scale
- Tablespoon
- Paper towels
- Labels
- 3 Balls
- Notebook for observations.



**Figure 4:** Photos displaying materials used during experiment.

## PRE - EXPERIMENTAL INFORMATION

Toothpaste solution was created by mixing 3 tablespoons of toothpaste with 450ml of water.

## METHOD

1. 20 eggs were hard-boiled and left to cool completely prior to the beginning of the experiment. An extra 2 were hard boiled in case one of the eggs cracked.
2. 18 beakers were labelled; for 3 of each solution: Water, Coke, Coffee, Gatorade, Vinegar, and Toothpaste solution. This process can be viewed in figure 5.
3. The initial mass of each egg was measured using a scale and recorded in a results table.
4. Then the pH level of each liquid was tested using pH strips and the results were recorded.
5. 1 egg was carefully placed into each beaker, and 150ml of each solution was poured over the corresponding label, ensuring the egg is fully covered.
6. A ball was placed over each egg which was placed inside the vinegar to prevent the eggs from rising out of the liquid.
7. All beakers were kept in the same environment at room temperature for three days to maintain consistent conditions.
8. Observations were made daily, including changes in colour, texture, and visible damage to the eggshells.
9. After three days, the eggs were removed from the liquids and gently dried using paper towel.
10. The final mass of each egg was measured and recorded.
11. The results were analysed by comparing the changes in mass, appearance, and texture of the eggs in each liquid.
12. A conclusion was then made about which liquids caused the greatest and least damage to the eggshells.

# PROCESSING AND ANALYSING DATA AND INFORMATION

## RESULTS TABLES

| IV: Solution        | pH Level | Starting Mass (g) | Ending Mass (g) | Change in Mass (g) |
|---------------------|----------|-------------------|-----------------|--------------------|
| Coke                | 3.67     | 55.419            | 54.922          | -0.497             |
| Gatorade            | 3.49     | 52.929            | 53.585          | +0.656             |
| Coffee              | 4.91     | 53.961            | 50.118          | -3.843             |
| Vinegar             | 3.46     | 51.286            | 49.514          | -0.423             |
| Toothpaste Solution | 6.38     | 53.651            | 54.074          | +0.423             |
| Water               | 6.18     | 55.420            | 56.440          | +1.020             |

**Table 1:** Raw data collected for Trial 1 (Egg 1). Initial and final mass, pH of each liquid, and the ending change in mass after 72 hours of immersion.

| IV: Solution        | pH Level | Starting Mass (g) | Ending Mass (g) | Change in Mass |
|---------------------|----------|-------------------|-----------------|----------------|
| Coke                | 3.45     | 53.650            | 56.013          | +2.363         |
| Gatorade            | 3.26     | 52.205            | 53.661          | +1.456         |
| Coffee              | 5.32     | 54.942            | 54.874          | -0.068         |
| Vinegar             | 3.56     | 50.171            | 48.707          | -1.464         |
| Toothpaste Solution | 6.33     | 51.169            | 50.064          | -1.105         |
| Water               | 6.18     | 51.333            | 52.075          | +0.742         |

**Table 2:** Raw data collected for Trial 2 (Egg 2). Initial and final mass, pH of each liquid, and the ending change in mass after 72 hours of immersion.

| IV: Solution        | pH Level | Starting Mass (g) | Ending Mass (g) | Change in Mass |
|---------------------|----------|-------------------|-----------------|----------------|
| Coke                | 3.84     | 51.598            | 56.588          | +4.990         |
| Gatorade            | 3.54     | 53.224            | 52.802          | -0.422         |
| Coffee              | 4.86     | 55.911            | 52.399          | -3.512         |
| Vinegar             | 3.54     | 53.405            | 51.928          | -1.477         |
| Toothpaste Solution | 6.33     | 49.801            | 51.220          | +1.419         |
| Water               | 6.19     | 51.866            | 53.513          | +1.647         |

**Table 3:** Raw data collected for Trial 3 (Egg 3). Initial and final mass, pH of each liquid, and the ending change in mass after 72 hours of immersion.

## SUMMARY TABLE

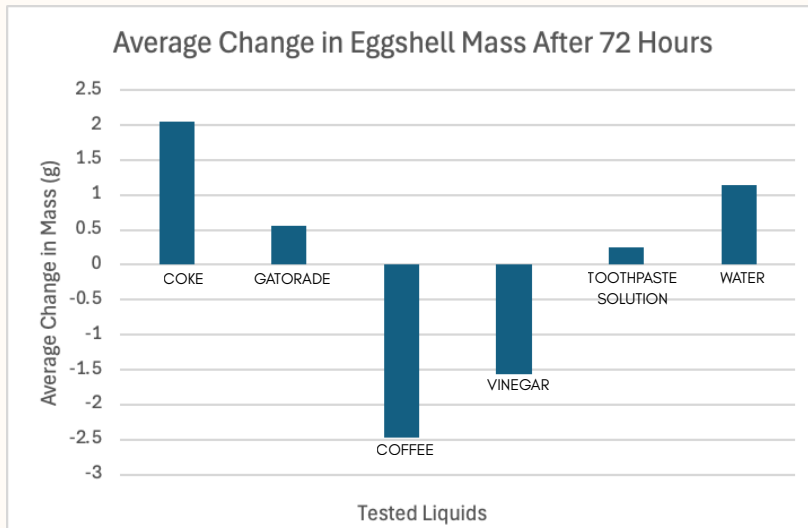
| IV: Solution        | Average pH Level | Average Starting Mass (g) | Average Ending Mass (g) | Average Change in Mass (g) |
|---------------------|------------------|---------------------------|-------------------------|----------------------------|
| Coke                | 3.653            | 53.556                    | 55.608                  | +2.052                     |
| Gatorade            | 3.430            | 52.786                    | 53.349                  | +0.563                     |
| Coffee              | 5.030            | 54.938                    | 52.464                  | -2.474                     |
| Vinegar             | 3.520            | 51.621                    | 50.050                  | -1.572                     |
| Toothpaste Solution | 6.347            | 51.540                    | 51.786                  | +0.246                     |
| Water               | 6.183            | 52.873                    | 54.009                  | +1.136                     |

**Table 4:** Processed data showing the average results for each liquid. Average pH, initial mass, final mass, and change in mass calculated from the three trials.

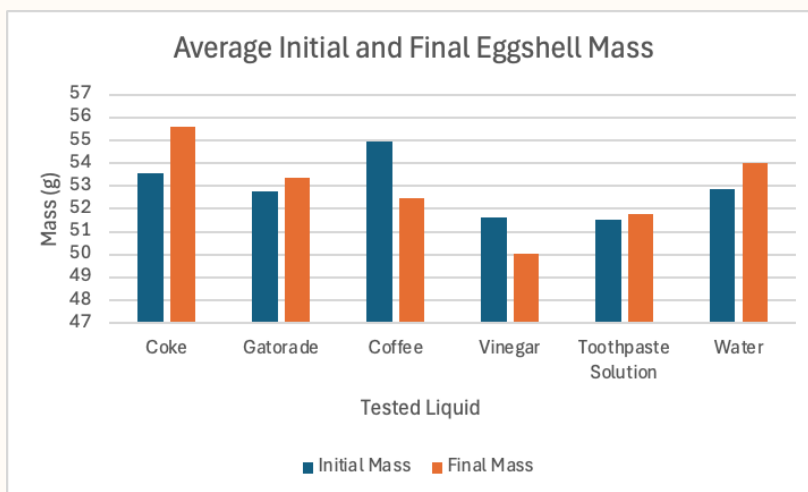


# PROCESSING AND ANALYSING DATA AND INFORMATION

## GRAPHS MADE FROM SUMMARY TABLE



**Figure 5:** Average change in eggshell mass after 3 days or 72 hours of immersion in various liquids. The graph compares the average change in eggshell mass following exposure to six liquids with varying pH levels. Positive numbers demonstrate increase in mass, while negative values indicate a decrease in mass.



**Figure 6:** Average initial and final eggshell mass subsequent to 3 days or 72 hours of immersion in different liquids.

# EVALUATION AND COMMUNICATION

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## DISCUSSION

The results demonstrated that different liquids had varying effects on the eggshells after 72 hours of immersion, as shown in Figure 5 and Figure 6. Across the different treatment groups, noticeable differences were recorded in mass change, colour alteration, surface texture, and visible structural deterioration. These variations indicate that the chemical composition of each liquid played a significant role in determining the extent of eggshell degradation.

Given that eggshells are mostly composed of calcium carbonate, they act as an effective model for investigating how acidic substances impact mineralised structures such as tooth enamel. This is because calcium carbonate reacts instantly with acids, allowing the experiment to simulate the process of demineralisation. The data presented in Figure 5 and Figure 6 clearly display differences in mass between the control and experimental groups. The results partially supported the hypothesis that liquids with greater acidic value would cause greater impact to the eggshells. Vinegar, which had one of the lowest pH values, created the most substantial erosion, as displayed by the largest decrease in mass illustrated in Figure 5 and the most severe surface deterioration. The eggshell surface became noticeably softened, roughened and smelt strongly of vinegar, which is consistent with acid reacting with calcium carbonate to produce soluble calcium compounds. This leads to mineral loss and structural weakening. This supports the expected chemical reaction between acids and carbonate-based materials. In contrast, eggs immersed in water and the toothpaste solution showed minimal visible damage (images can be seen in the log book) and only minor changes in mass in Figure 1. This suggests that liquids with higher or neutral pH levels are significantly less likely to contribute to demineralisation. In the case of toothpaste solution, the presence of fluoride and alkaline compounds may have helped reduce mineral loss or create a protective effect on the shell surface.

However, some results did not fully follow the expected trend. As seen in Figure 1, certain liquids resulted in an increase in mass rather than the anticipated decrease. This may be explained by absorption of liquid into the porous structure of the eggshell, which could temporarily increase overall mass even if mineral was lost, occurring simultaneously. Additionally, staining from coffee and Coca-Cola which was also evident, altered the appearance of the eggshells significantly. These changes suggest that beyond structural damage, pigments and dissolved compounds in these beverages can adhere to or penetrate the eggs' surface.

Overall, the investigation demonstrated a general relationship between liquid acidity and eggshell deterioration, as supported by the trends in Figures 5 and 6. However, the results also indicate that factors beyond pH—such as sugar content, colouring agents, and overall chemical composition—may have influenced the extent of damage observed. This means that while acidity is a key factor in demineralisation, it is not the only variable affecting the outcomes of the experiment.

# EVALUATION AND COMMUNICATION

## SYSTEMATIC ERROR

**Table 5:** A table displaying the systematic errors that could have possibly impacted results.

| Systematic Error                | Effect on Results                                                                      | Improvement                                                                |
|---------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Digital scale error             | All mass measurements may have been consistently higher or lower than the true values. | Calibrate the scale before collecting data.                                |
| Inaccurate pH testing method    | pH values may not have represented the true acidity of the liquids.                    | Use a calibrated digital pH meter.                                         |
| Variation in eggshell thickness | Some eggs may have been naturally more resistant to erosion.                           | Measure shell thickness before the experiment or use a larger sample size. |

## RANDOM ERROR

**Table 6:** A table displaying the random errors that could have possibly impacted results.

| Random Error                                         | Effect on Results                                                      | Improvement                                                     |
|------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------|
| Small differences in drying the eggs before weighing | Residual liquid may have increased some mass measurements.             | Dry all eggs using the same procedure and time period.          |
| Minor variations in pH measurements                  | Slight differences between readings may have affected recorded values. | Take multiple pH measurements and calculate an average.         |
| Accidental handling differences                      | Additional pressure may have damaged some eggshells.                   | Minimise handling and use consistent procedures for all trials. |

## Limitations

- Eggshells are not identical to human tooth enamel and therefore may not react in exactly the same way.
- The investigation was conducted over only 3 days, which does not fully depict long-term exposure.
- Only six liquids were tested, limiting the range of comparisons that could be made.
- Changes in mass alone may not accurately represent the total extent of erosion.

## Strengths

- Three trials were conducted for each liquid, improving reliability.
- The pH of each liquid was measured rather than assumed.
- Multiple control variables were maintained throughout the investigation.
- Both quantitative (mass) and qualitative (visual observations) data were collected.



# EVALUATION AND COMMUNICATION

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## **FUTURE INVESTIGATION**

Future investigations could observe a greater range of liquids, such as juices, energy drinks, flavoured waters or tea. The immersion period could also be extended surpassing 3 days to investigate long-term effects. Furthermore, additional measurements such as shell thickness, hardness, or surface area changes could be gathered to provide a more comprehensive analysis of erosion.

## **CONCLUSION**

This investigation aimed to determine how different liquids affect eggshells used as a model for tooth enamel. The results indicated that liquids with lower pH values generally caused greater changes to the eggshells than liquids with higher pH values. Vinegar produced the greatest visible erosion and softening, while water and the toothpaste solution produced the least noticeable effects. Therefore, the hypothesis was largely supported, as acidic liquids were found to have a greater impact on eggshell deterioration than neutral or alkaline liquids. These findings suggest that frequent exposure to acidic beverages may contribute to the demineralisation of tooth enamel over time.

## **ACKNOWLEDGEMENTS**

Ms Sampson (Science teacher) perceptively answered my questions about various ideas and helped brainstorm ideas which improved the investigation.

Preet (lab tech) kindly provided several apparatus including pH strips, eggs and other liquids. Preet also conducted tests when I was away and not able to.

## **WORD COUNT**

**1997 Words** (Excluding headings, titles, tables, figure captions, Acknowledgements, reference list, and logbook)

# REFERENCE LIST

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# LOG BOOK



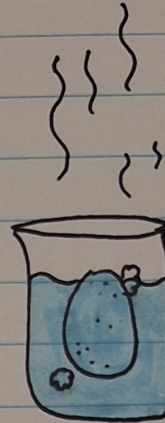
5.3.26

# oliphant

## HOW DIFFERENT DRINKS EFFECT TOOTH ENAMEL

### TESTING DIFFERENT DRINKS:

- COFFEE
- ENERGY DRINKS - Redbull, batorade
- WATER
- Soft drinks - Coke, Sprite
- Tea
- Mouthwash



### ↳ USING EGG SHELLS

- Shells and tooth enamel have similar chemical compositions
- They react similarly with chemicals
- Both made of calcium based products
  - ↳ EGG SHELLS: calcium carbonate ( $\text{CaCO}_3$ )
  - ↳ ENAMEL: calcium phosphate ( $\text{Ca}_{10}\text{PO}_4$ )
- Both hard, thin and brittle

### EXPERIMENT

- Soak eggs in the different liquids (How long?)
- Remove them + check the effect (if it has eroded)

24hrs? or a week?

\* MAYBE: Use toothpaste to see if it works?

↳ Compare it to a healthy tooth under a microscope?

↳ How the different components in the liquids affected the tooth (eggs)

↳ DIFFERENT: test if different types of toothpaste works

- |                        |                          |
|------------------------|--------------------------|
| • Charcoal toothpaste  | • Fluoride toothpaste    |
| • Whitening toothpaste | • Natural toothpaste     |
| • Sensitive toothpaste | • Anti-plaque toothpaste |
| • Kids toothpaste      |                          |



# EXPERIMENT ~~elephant~~ silver awards

## Materials:

- 8 eggs
- Coffee, redbull, gatorade, water, coke, sprite, tea, mouthwash
- 8 beakers

**Aim:** To test the effects of popular drinks on tooth enamel

**Hypothesis:** The drinks with more acid e.g. sprite, coke, gatorade will have a greater effect.

**PH LEVELS** : How ACIDIC OR BASIC (alkaline) a water-based solution is

COFFEE: SPRITE:

REDBULL: TEA:

GATORADE: MOUTHWASH:

WATER:

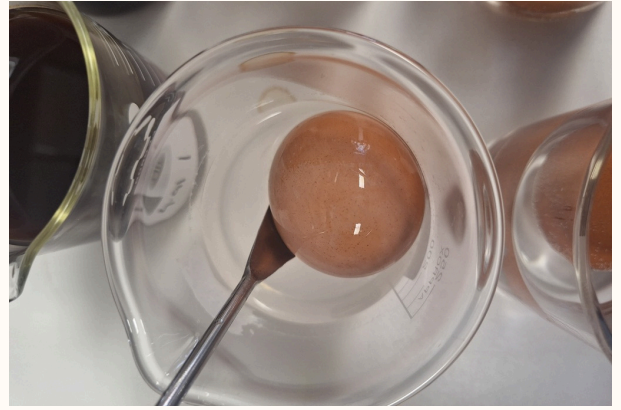
COKE:



## DAY 1 - 26 MAY



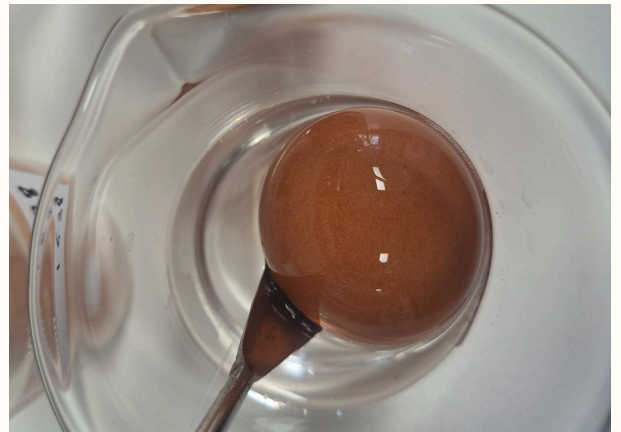
Gatorade:



Toothpaste solution:



Vinegar:



Water:



Coca - Cola:



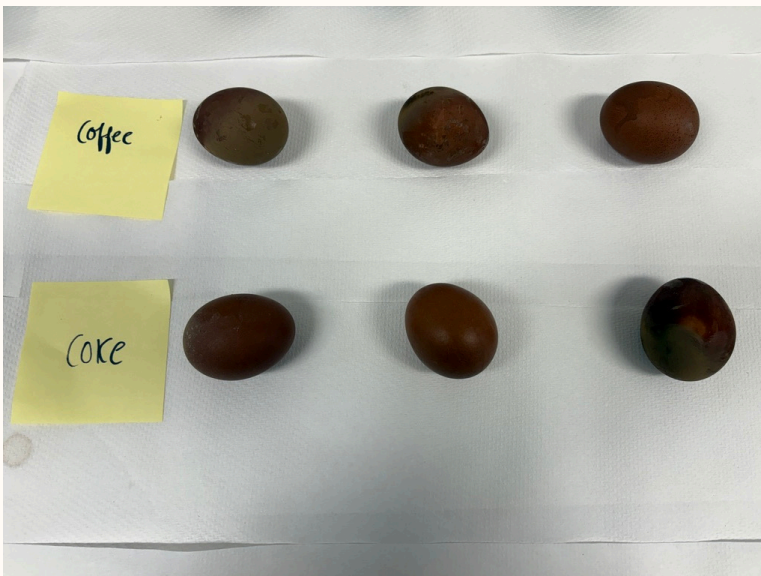
Coffee:

## DAY 3 - 28 MAY



Vinegar

Gatorade:



Coffee:

Coke:



Toothpaste:

Water:



Vinegar

Gatorade

Coffee

Coke

Toothpaste

Water





# FINAL MASSES

|       | 1         | 2         | 3         |
|-------|-----------|-----------|-----------|
| Water | pH = 6.18 | pH = 6.19 | pH = 6.15 |
|       | 56.440    | 53.513    | 52.075    |

---

|            | 1      | 2      | 3      |
|------------|--------|--------|--------|
| toothpaste | pH =   |        |        |
|            | 54.074 | 51.220 | 50.064 |

---

|      | 1                         | 2      | 3      |
|------|---------------------------|--------|--------|
| coke | <del>56.5</del><br>54.922 | 56.588 | 56.013 |

---

|        | 1      | 2      | 3      |
|--------|--------|--------|--------|
| coffee | 50.118 | 52.399 | 54.874 |

---

|          | 1      | 2      | 3      |
|----------|--------|--------|--------|
| Gatorade | 53.585 | 52.802 | 53.661 |

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|         | 1      | 2      | 3      |
|---------|--------|--------|--------|
| vinegar | 49.514 | 51.928 | 48.707 |



# OSA RISK ASSESSMENT FORM

for all entries in ☒ Models & Inventions and ☐ Scientific Inquiry

This must be included with your report, log book or entry. One form per entry.

STUDENT(S) NAME: Sepo Simasiku ID: 0765-068

SCHOOL: Walford Anglican School for girls

Activity: Give a brief outline of what you are planning to do.

This investigation aimed to examine the effects of different liquids on hard-boiled eggs, used as a model of a human tooth. Six liquids with different pH levels - water, Coca-Cola, coffee, Gatorade, vinegar and a toothpaste solution. Three eggs were immersed in each liquid. Daily checks were made and the changes were written down.

Are there possible risks? Consider the following:

- Chemical risks: Are you using chemicals? If so, check with your teacher that any chemicals to be used are on the approved list for schools. Check the safety requirements for their use, such as eye protection and eyewash facilities, availability of running water, use of gloves, a well-ventilated area or fume cupboard.
- Thermal risks: Are you heating things? Could you be burnt?
- Biological risks: Are you working with micro-organisms such as mould and bacteria?
- Sharps risks: Are you cutting things, and is there a risk of injury from sharp objects?
- Electrical risks: Are you using mains (240 volt) electricity? How will you make sure that this is safe? Could you use a battery instead?
- Radiation risks: Does your entry use potentially harmful radiation such as UV or lasers?
- Other hazards.

Also, if you are using other people as subjects in an investigation you must get them to sign a note consenting to be part of your experiment.

| Risks                                                  | How I will control/manage the risk                                               |
|--------------------------------------------------------|----------------------------------------------------------------------------------|
| • Burns from boiling water for eggs.                   | • Letting the cool completely before use and making sure it is not spilled.      |
| • Spilling liquids such as gatorade coffee or vinegar. | • Putting the lid on the bottle after use and cleaning up the spill immediately. |
| • Skin or eye irritation from acidic liquids.          | • Avoid direct contact with liquids and washing hands after handling.            |
| • Bacteria growth from eggs left in liquid.            | • Dispose of materials after experiments.                                        |

(Attach another sheet if needed.)

Risk Assessment indicates that this activity can be safely carried out

RISK ASSESSMENT COMPLETED BY (student name(s)): Sepo Simasiku

SIGNATURE(S): Sepo

☒ By ticking this box, I/we state that my/our project adheres to the listed criteria for this Category.

TEACHER'S NAME: Alicia Sampson

SIGNATURE: [Signature] DATE: 25/6/2026