Chemistry IA

How does increasing the temperature of Broccoli affect the vitamin C concentration in $moldm^{-3}$

Candidate code:

Introduction

The idea of conducting my research began when a deadly virus called Covid-19 was on a rise and the second wave was going to arrive. During this peak time the government and all other health organizations were pushing out posters, which talked about the necessary SOPs (standard operating procedure) and healthy diet/supplement options to avoid catching Covid-19 and to increase immunity. During this pandemic I came across and article by “NCBI -Diagnostic” (NCBI -Diagnostic, 2022) which talked about the vitamin concentrated vegetables and how they should be eaten at rather cold temperatures than at hot temperatures.

At the start this seemed like an assumption a random article on the internet is making, although after some research I found out that temperature affects vitamin C contents in vegetables, and vitamin C is an essential nutrient that plays a critical role in maintaining good health. Vitamin C is also a fragile nutrient that can easily degrade due to heat, light, and other environmental factors. Therefore, understanding how temperature affects vitamin C concentration in broccoli is of significant personal and global relevance. The answer to this question can help individuals make informed decisions about the best ways to cook and store broccoli to maximize its nutritional value. Thus, I was curious about the optimal temperature for maximizing vitamin C content in vegetables (Broccoli), so I conducted an experiment. As a result, I performed a redox titration with iodine solution to investigate the relationship.

Background Information

The most prevalent electroactive biological ingredient discovered in several fruit species is vitamin C (ascorbic acid, ascorbate, AA). It is an organic chemical that is water soluble and is used in numerous biological activities. The world's populace takes this supplement more than any other (Chowdhury, Mohammed, 2016). All living things absolutely need vitamin C. L-Ascorbic Acids are what most people think of when they hear that term. Phytochemicals, vitamins, minerals, dietary fiber, and other nutrients are essential for human health, and vegetables and fruits provide many of these essential nutrients (familyeducation.com, 2017). Consuming veggie and fruit-rich diets have been shown to protect the body from chronic degenerative diseases. As an antioxidant, it plays a crucial role in human nutrition and overall health. As vitamin C is not something the body can produce on its own, getting enough of it through food is crucial. Vitamin C aids the immune system, helps the body absorb iron, speeds wound healing, promotes collagen production (which is good for the skin), and helps fight off bacterial and viral infections. Deficiency of vitamin C can lead to a condition called scurvy, which is characterized by symptoms such as bleeding gums and skin, tooth loss, joint pain, and fatigue. Vitamin C is found in many different foods, but it is easily destroyed by cooking at too high of a temperature. Vitamin

C undergoes oxidation when exposed to heat, light, and oxygen in the air. Vitamin C, being water-soluble, can be easily lost into cooking water and thus destroyed (Igwemmar et al., 2013).

Free radicals are unstable chemicals that can damage cells and contribute to the development of chronic diseases like cancer and heart disease. Vitamin C is a strong antioxidant that helps to protect cells from damage caused by free radicals. Collagen, a protein crucial to the development of skin, tendons, ligaments, and blood vessels, cannot be manufactured without vitamin C. Hydronium ions are produced when vitamin C, a weak acid, partially dissociates in water. Vitamin C is an antioxidant that is crucial to many different bodily functions. C6H8O6 is the formula for ascorbic acid, a chemical with six carbon atoms. London dispersion forces, hydrogen bonds, and dipole-dipole bonds all play a role in keeping the many atoms that make up vitamin C's complex together.

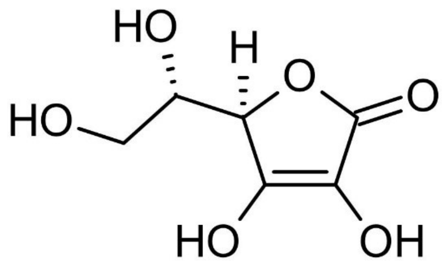


Figure 1: Ascorbic Acid Molecular Structure (abcam.com)

Redox titration is a type of titration that involves the transfer of electrons between two reactants. Iodine solution is commonly used in redox titrations because it is an excellent oxidizing agent and can readily accept electrons from reducing agents. In a typical redox titration using iodine solution, a reducing agent is titrated with a standard solution of iodine. The reaction between the reducing agent and iodine produces iodide ions and an oxidized form of the reducing agent.

Ascorbic acid is converted to dehydroascorbic acid and iodine is reduced to iodide ions in this titration.

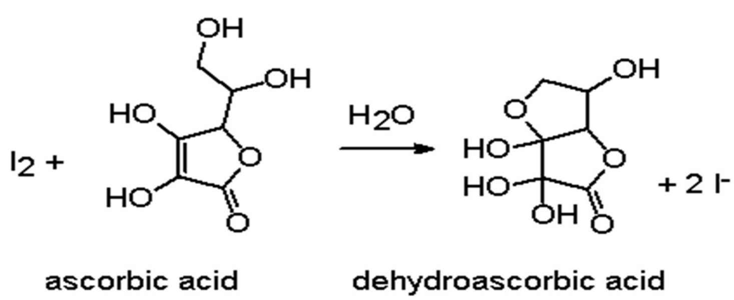


Figure 2: Iodine and Ascorbic Acid Reaction (https://staff.buffalostate.edu/)

Reduction half equation: $I_2 + 2e^- \longrightarrow 2I^-$

Oxidation half equation: $C_6H_8O_6 \longrightarrow C_6H_6O_6 + 2H^+ + 2e^-$

As long as ascorbic acid is present, the iodine formed in this reaction is quickly converted to iodide. Excess iodine is released when ascorbic acid is oxidized to its inactive state; this iodine then reacts with the starch indicator, producing a blue-black starch-iodine complex. The titration is finished at this stage (University of Canterbury, 2016). In the presence of iodine, ascorbic acid is oxidized (loses electrons), and iodine is reduced (gains electrons). Dehydroascorbic acid and iodide ion are produced along with iodine when ascorbic acid is present in the solution (John Olson, n.d.).

Starch is utilized as an indicator in this reaction because, after the ascorbic acid is entirely oxidized, the excess iodine can react with the starch solution, turning the starch blue-black and marking the endpoint of the titration, whereas in the absence of iodine, the starch stays milky-white (University of Canterbury, 2016).

Research Question

How does increasing the temperature of Broccoli affect the vitamin C concentration in $moldm^{-3}$, with varied temperatures of 20, 30, 40, 50, 60 degrees Celsius through redox titration using iodine solution?

Hypothesis

Excessive heat and water can easily destroy vitamin C. The vitamin C content of broccoli decreases as the temperature rises.

Hypothetically vitamin C can be destroyed by heat and light, the concentration of vitamin C in broccoli should decrease as the temperature rises. When exposed to high heat or prolonged cooking, vitamin quality can deteriorate. It can leach into cooking liquids and be lost if the liquids are not consumed because it is water-soluble (harvard.edu, 2021)

Variables

Table showing Variables in the experiment	
Independent Variable	The 20 mL aliquot of broccoli will be refrigerated or heated on a Bunsen burner at 20°C, 30°C, 40°C, 50°C, and 60°C with 10°C increments until the desired temperature is reached. This temperature interval was chosen because 10 degrees between trials is sufficient to ensure that the vitamin C of the aliquot changes at significant intervals, allowing me to easily map the trends of the data received. A thermometer will be used to measure the temperature. A thermometer will be used to measure the temperature. For accurate results, five trials will be conducted.
Dependent variable	The concentration of vitamin C is the dependent variable since it determines how temperature affects vitamin C content/ascorbic acid. The concentration will be determined by the volume of potassium iodate solution that reacted with the aliquot during the redox titration. Vitamin C concentration can be calculated using stoichiometry: moles of ascorbic acid substituted into concentration = moles/volume yields the final concentration. Each temperature will be measured and correlated in mol dm^{-3}.

Table: 1 showing the independent and dependent variables of the experiment

Table showing the Controlled Variables of the experiment	
Variable	**Explanation**
Type of broccoli	The broccoli used in this experiment will be will be bought on the same day as the experiment, so that the broccoli is fresh. The samples will be prepared before the titration to avoid oxidation. In addition, once the sample is obtained, a lid will be put back on to prevent oxidation or other contamination. The broccoli used in this experiment will bought by the same retailer, to get constant vitamin C in the samples.
Volume of analyte in titration	The broccoli aliquot serves as the titration's analyte. Each 20 mL aliquot of broccoli will receive 150 mL of distilled water during the trials. As a result, the analyte volume is bound to remain at 170 ml. The volume of the aliquot must remain constant because the broccoli is a component of the analyte. Changing the volume of the aliquot in the analyte has a direct impact on the ascorbic acid concentration. Volume must not change because temperature is the only independent variable; therefore, only temperature can be used to compare temperature and not volume
Volume of starch indicator	The same amount of starch indicator will be used for each trial. If different amounts are added, the end result will be affected, and the concentration of the final result may alter, hence reducing the experiment's accuracy. I will add 1 mL of starch indicator.
Same iodine solution	The iodine solution concentration will be kept constant. Throughout the experiment, a 0.005M solution will be used. Concentration must be controlled because it can change reaction speed and cause the reaction to finish sooner, hence distorting the results.

Table: 2 showing the controlled variables of the experiment

Methodology

Apparatus:

Apparatus and materials used in the experiment			
Material	**Quantity and Uncertainty**		
Broccoli	100 grams	Distilled water	≈ 3 liters
Soluble starch	0.25 grams	Weighing scale	± 0.1 grams
Conical flask	$250cm^3$	Thermometer	± 0.05 degrees
Knife	1	Dropper	2
Mortar and pestle	1	Cooling tile	1
Cheese cloth	$30 \times 30cm^3$	Stirring rod	1
Graduated cylinder	25.00 ± 0.25ml	Bunsen Burner	1
Burette	100 ± 0.01ml	Tripod	1
Retort stand	2	Wire Gauze	1
		Iodine solution	≈ 500 ml 0.005 molL^{-1}

Table: 3 showing the Apparatus and materials used in the experiment

Procedure:

Preparations of solutions needed

Iodine solution preparation: (0.005 $mol\ L^{-1}$)

1. Weigh and place 1 g potassium iodide in a 100 mL beaker.
2. In the same beaker, put 0.65g of iodine.
3. Mix the iodine with small amount of distilled water and stir it for a few minutes in order to dissolve it.
4. Thereafter, pour the iodine solution into a 0.5 L volumetric flask.
5. Bring the volume up to 0.5 L with distilled water.

Starch indicator solution preparation: (0.5%)

1. Weigh 0.25 grams of soluble starch
2. Fill a 100 mL conical flask halfway with 50 mL of almost boiling water.
3. Stir the solution to dissolve and allow it to cool before using

Titration:

1. Wash 100 g of broccoli in distilled water, cut the sample into small pieces and pound in a mortar and pestle.
2. Add 10 mL increments of distilled water while grinding the sample, decanting the liquid extract into a 100 mL volumetric flask each time.
3. The broccoli should be strained using cheesecloth, with the pulp being washed with several 10 mL increments of distilled water, and the resulting filtrate and washings being collected in the volumetric flask.
4. Put in enough distilled water to bring the total volume of the extracted solution up to 350 mL.
5. Place 1 mL of the starch indicator solution, 150 mL of distilled water, and 20 mL of the sample aliquot in a 250 mL conical flask using a pipette.
6. Install a burette into a retort stand and add the 0.005 $mol\ L^{-1}$ iodine solution until the burette reads the 0 mL/cm^3.
7. Safely light up the Bunsen burner and place a wire gaze on top of the tripod.
8. Place the conical flask on top of the wire gaze, taking care that the thermometer does not touch the flask.
9. Once the temperature reaches 30 degrees Celsius, remove the sample solution with tongs and set it on the cooling tile. (Note: that we got temperatures as low as 20 degrees Celsius by putting the sample aliquot in the freezer.)
10. Using iodine solution titrate the sample. The flask should be continously swirled until the endpoint is reached.
11. Close the tap when the solution becomes a dark blue-black color.

12. Repeat steps 5-11 for the other remaining temperatures conducting 5 trials for each temperature. Record the readings obtained from the burette.

Setup the experiment as shown in the picture below.

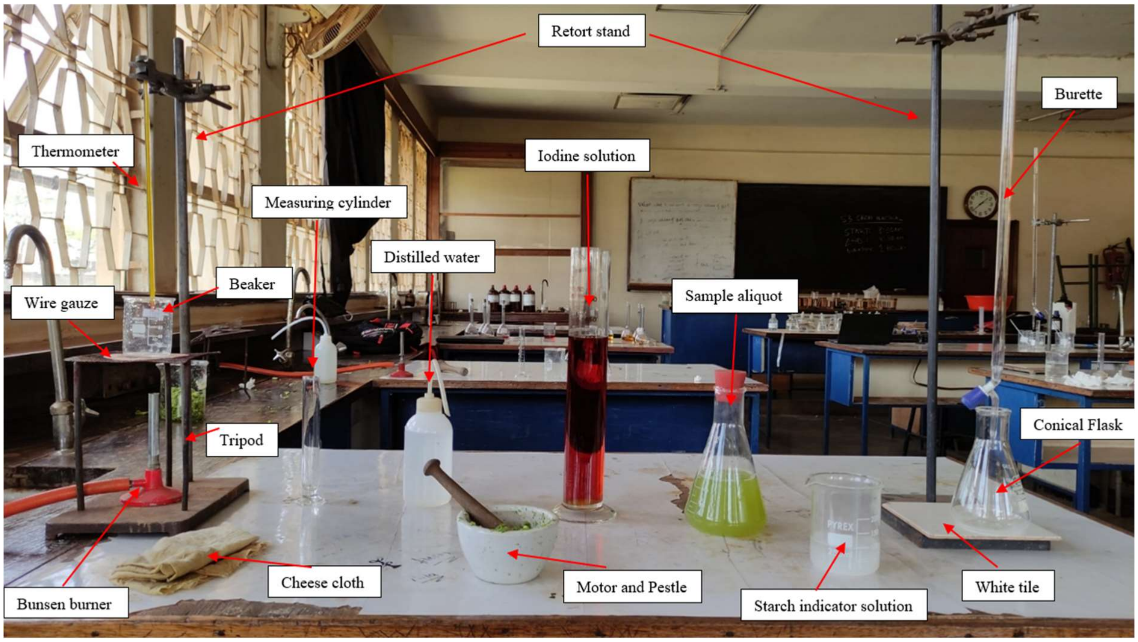


Figure 3: Picture showing experimental setup

Safety and ethical concerns:

- Wear Safety goggles and a lab coat which will keep you safe from the flame and the highly staining iodine solution. Even though the iodine solution is diluted, it is still important to take precautions to avoid inhaling or ingesting any of the vapors that may be present. Any contact with an eye containing a solution "The eye should be flushed with cool running water for 10 minutes before medical attention is sought. " You should get some fresh air if you've been breathing in vapor, and see a doctor if your breathing has slowed down at all. Consuming an iodine solution can cause "Just gargle with water and see if that helps. The iodine solution can irritate the skin and cloth if it comes into contact with either." Remove all potentially contaminated garments and thoroughly soak the skin in water. Get medical help if the problem spreads over a wide area.

- Potassium iodide can cause irritation. The skin and eyes can be severely irritated if this comes into contact with them. Preparing chemicals in a fume hood to make more diluted solutions is one way to lessen exposure, and workers should always wear protective gear like goggles and gloves while handling chemicals. Exposure to Potassium Iodide fumes necessitates the use of emergency eye wash as prescribed or prolonged rinsing with large quantities of water for many minutes until professional medical assistance can be sought. After the experiment is completed, all excess Potassium Iodide should be disposed of in a hazardous waste bin. Inhalation of the potassium iodide can result in asphyxia, chemical pneumonitis, and acute pulmonary edema.

- These risks can be minimized by diluting chemicals in a fume hood and protecting one's eyes and hands with protective gear. In case of exposure to Potassium Iodate fumes, immediately rinse your eyes with water for several minutes. After the experiment, put any leftover potassium iodate in a proper hazardous waste container for disposal.

Results

Experiment results: Table 4						
Temperature of mixture (±0.1°C)	Volume of 0.005M iodine solution used (±0.5 cm^3/mL)					
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
20	11.4	11.8	12.1	11.2	12.8	11.8
30	9.60	9.30	9.20	9.70	9.20	9.40
40	7.00	6.50	6.80	7.00	6.70	6.80
50	4.30	4.10	4.30	4.00	4.30	4.20
60	3.20	3.50	3.40	3.60	3.30	3.40

Qualitative observation: The aliquot appeared to be a deep green in color. During the titration, as more iodine solution was added the color of the solution turned dark blue to neutralize the ascorbic acid. After the ascorbic acid has been completely oxidized, the solution turns a dark blue color due to the formation of a complex between the starch indicator and an excess of iodine added during the titration. This dark blue color marks the endpoint of the titration.

Data processing and Uncertainty progression

From the data obtained, Ascorbic acid concentration can be determined from the collected data by molar mass, mole ratio and the volume equation.

Calculating concentration of ascorbic acid:

Using 20°C as an example

Table 5: Data processing to calculate the concentration of Vitamin C	
Data Processing	**Uncertainty Propagation**

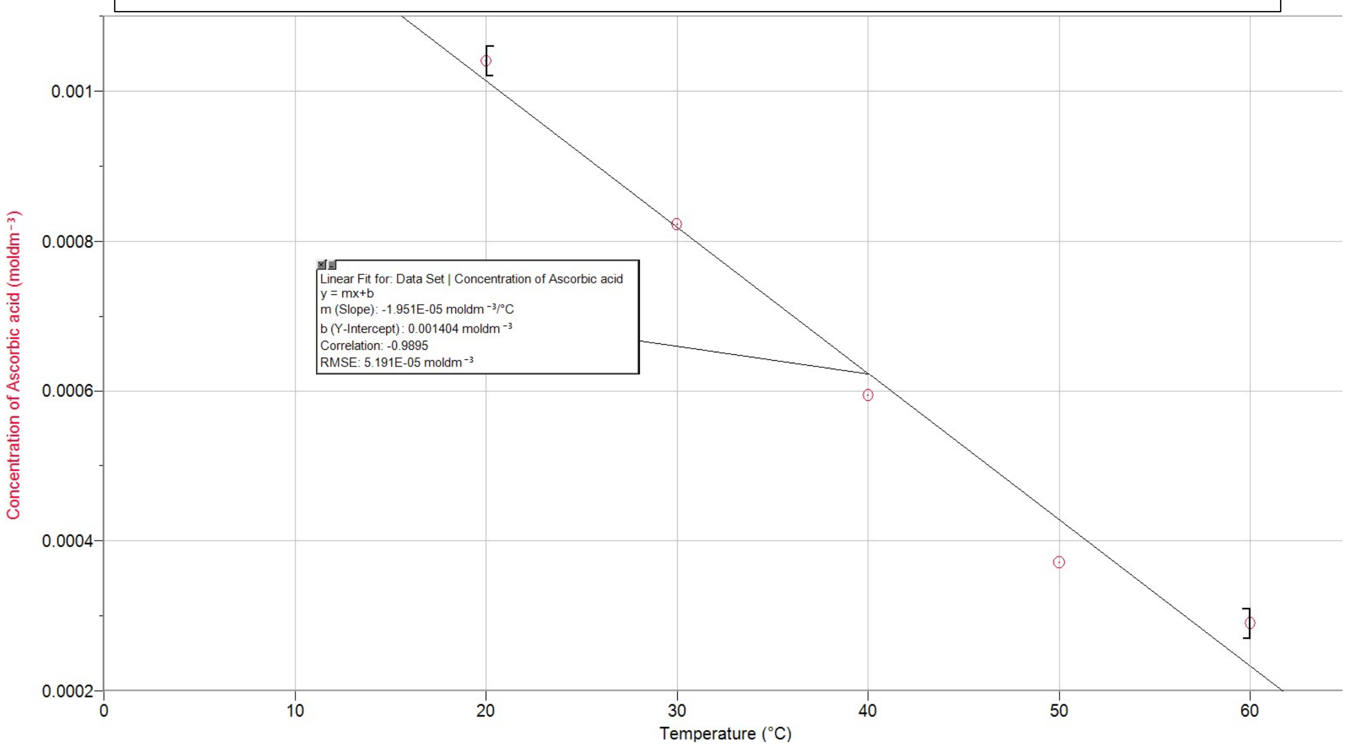
Average volume of iodate solution $Average = \frac{Trial\ 1 + Trial\ 2 + Trial\ 3\ + Trial\ 4 + Trial\ 5}{5}$ $Average = \frac{11.4 + 11.8 + 12.1 + 11.2 + 12.8}{5}$ $Average = 11.82$ $\approx 11.8\ \text{cm}^3$	$UC = Uncertainity$ $UC = \frac{0.10 + 0.10 + 0.10 + 0.10 + 0.10}{5}$ $= 0.10$
Average volume of iodate solution: $\mathbf{11.82 \pm 0.10\ cm^3}$	
Moles of iodate that reacted to form iodine $moles = \frac{0.005 \times 11.82}{1000}$ $moles = 5.91 \times 10^{-5}$	$\frac{UC\ Concentration}{Concentration} = \frac{UC\ A}{A} + \frac{UC\ B}{B}$ $\frac{UC\ Concentration}{5.91 \times 10^{-5}} = \frac{0.10}{0.65} + \frac{0.10}{1000}$ $UC\ Concentration = 9.09 \times 10^{-6}$
Moles of Iodate formed: 5.91$\times$ $\mathbf{10^{-5} \pm 9.09 \times 10^{-6}}$	
Moles of iodine produced using the reaction between iodate and iodide ions $IO_3^- + 6H^+ + 5I^- \rightarrow 3I_2 + 3H_2O$ = Mole ratio: 1:3 $= 3 \times (5.91 \times 10^{-5})$ $= 1.77 \times 10^{-4}$	$UC \times 3\ as\ mole\ ratio\ is\ being\ multiplied\ by\ 3$ $UC = 9.09 \times 10^{-6} \times 3$ $= 2.73 \times 10^{-5}$
Moles of Iodine formed: $\mathbf{1.77 \times 10^{-4} \pm 2.73 \times 10^{-5}}$	
$Ascorbic\ acid + I_2 \rightarrow 2I^- + Dehydroascorbic\ acid$ = Mole ratio 1:1 $= 1 \times (1.77 \times 10^{-4})$ $= 1.77 \times 10^{-4}$	$UC = 2.73 \times 10^{-4} \times 1$ $= 2.73 \times 10^{-5}$
Moles of Ascorbic acid reacting: $\mathbf{1.77 \times 10^{-4} \pm 2.73 \times 10^{-5}}$	
$Concentration = \frac{Number\ of\ moles}{Volume}$ $= \frac{1.77 \times 10^{-4}}{171/1000}$	$\frac{UC\ C}{C} = \frac{UC\ A}{A} + \frac{UC\ B}{B}$ $\frac{UC\ C}{1.04 \times 10^{-3}} = \frac{2.73 \times 10^{-5}}{1.77 \times 10^{-4}} + \frac{0.25}{20}$

$= 1.04 \times 10^{-3}\ moldm^{-3}$	$= 1.73 \times 10^{-4}$ **Percentage Uncertainty** $\frac{Absolute\ UC}{Measured\ value} \times 100$ $\frac{1.73 \times 10^{-4}}{1.04 \times 10^{-3}} \times 100$ $= 16.6\%$
Concentration of Ascorbic acid: $\mathbf{1.04 \times 10^{-3} \pm 1.73 \times 10^{-4}}$	

Table 6: Showing processed data for each variation of the independent variable

	Temperature / °c				
	20	**30**	**40**	**50**	**60**
Concentration of Ascorbic acid / $moldm^{-3}$	1.04×10^{-3}	8.22×10^{-4}	5.94×10^{-4}	3.71×10^{-4}	2.90×10^{-4}
Absolute uncertainty	1.73×10^{-4}	1.37×10^{-4}	9.85×10^{-5}	6.16×10^{-5}	3.46×10^{-5}
% Uncertainty	16.6%	16.66%	16.58%	16.60%	11.93%

Graph showing Concentration of Vitamin C $moldm^{-3}$ for the temperatures 20°C, 30°C, 40°C, 50°C, and 60°C.



Graphical interpretation

As can be seen from the above graph, the concentration of vitamin C (or ascorbic acid) has a constant negative linear correlation with increasing temperature. The negative linearity of the graph is demonstrated by the regression line's equation, which reads $y = -0.00001951x + 0.001404$. Since the R^2 value for this regression line is 0.9895 it is clear that it provides the best fit for the data. This demonstrates that there is a negative linear relationship between ascorbic acid concentration and temperature, and that the regression line accurately represents this relationship. Since vitamin C is heat sensitive and heat has a negative impact on molecule stability, this trend at when temperatures rose, vitamin C levels would decrease. The graph and data support the hypothesis of a negative correlation between the two variables. Final results demonstrate that as temperature is increased from 20°C to 60°C, ascorbic acid concentration is reduced from $1.04 \times 10^{-3}\ moldm^{-3}$ to $2.9 \times 10^{-4}\ moldm^{-3}$. There is a strong negative correlation shown by the graph.

We can conclude from the % uncertainty that the experiment was relatively accurate, with more systematic errors than random ones. Overall, consuming broccoli cold and unheated is the best way to maximize the nutrient's vitamin C content. Cooking broccoli at high temperatures, such as boiling or microwaving, can cause a significant loss of vitamin C. Steaming or sautéing broccoli at lower temperatures can help to preserve more of the vitamin C content. Hence temperature and storage conditions can severely impact ascorbic acid levels, resulting in insufficient vitamin C intake.

Conclusion

The purpose of this study was to observe what happens to the vitamin C content of the sample aliquot as the temperature is raised. It was hypothesized that as temperatures increased, vitamin C concentrations would become depleted. Both the data and the graph confirm the expected inverse relationship between the two factors. Final results demonstrate that as temperature is increased from 20°C to 60°C, ascorbic acid concentration is reduced from $1.04 \times 10^{-3}\ moldm^{-3}$ to $2.9 \times 10^{-4}\ moldm^{-3}$. There is a strong negative correlation shown by the graph.

We can conclude from the % uncertainty that the experiment was relatively accurate, with more systematic errors than random ones. Overall, consuming broccoli cold and unheated is the best way to maximize the nutrient's vitamin C content. Cooking broccoli at high temperatures, such as boiling or microwaving, can cause a significant loss of vitamin C. Steaming or sautéing

broccoli at lower temperatures can help to preserve more of the vitamin C content. Hence Ascorbic acid content can be negatively affected by temperature and storage conditions, leading to inadequate vitamin C intake. In conclusion, increasing the temperature of broccoli can lead to a significant reduction in vitamin C concentration. This is because vitamin C is a fragile nutrient that can easily degrade due to heat. The loss of vitamin C in broccoli can vary depending on the temperature, the cooking time, and the cooking method used. For example, boiling broccoli for an extended period at high temperatures can cause a considerable loss of vitamin C. Therefore, it is essential to consider the cooking method and temperature when preparing broccoli to ensure that the maximum amount of vitamin C is retained. Overall, the findings of this study emphasize the importance of understanding the effect of temperature on vitamin C concentration in broccoli to ensure that we get the most nutritional value from this healthy vegetable.

Evaluation

Strengths:

- Five trials were carried out at each temperature. This ensured that some of the random error was eliminated, making the data collected more accurate and reliable.
- Simple to carry out because all the necessary equipment is pretty standard in any decent chemistry lab. In addition, the experiment was not overly complex or necessitated any special knowledge or equipment.

Limitations:

Table 7: Showing Limitations in the experiment

Limitations	Impact on results	Improvement
Random error: Determination of endpoint	Titration endpoints are visually determined and therefore inconsistent across trials, making it difficult to pinpoint when the reaction would stop. The black color produced by the iodine solution made it hard to tell when the titration process had completed.	Endpoint sensitivity can be decreased by rerunning trials in which it was not clearly observed, which will also improve endpoint detection accuracy. There will be fewer unaccounted-for errors, increasing confidence in the collected data. Also, since this is not an acid-base titration, measuring electrical conductivity as a proxy for concentration seems like the way to go.
Lack of theoretical data	Since there is no theoretical data to use for comparison and calculating the % error, and since this experiment is unique, we cannot draw any firm	Theoretical values are necessary to allow for comparisons and a discussion of the data's accuracy in order to determine whether or not

	conclusions about the results. I accepted the 20 degrees value as theoretical data (as it hadn't been altered with) for the subsequent variations with 30, 40, 50 and 60 degrees and calculated the % change as the temperature rose, as opposed to the percentage inaccuracy. I also found that the theoretical data I utilized was not very applicable to my experiment, as the theoretical value of concentration was lower than my value. This discrepancy is unusual and may be the result of utilizing different brands of broccoli.	the experiment was successfully carried out. In the future, conducting research on theoretical data before starting an experiment would be one way to get around this restriction. Another choice would be to change the research question to look into aspects that other researchers have already looked into. Given that the entire experiment has already been performed, a similar experiment could be repeated using these values as the theoretical data.
Systematic: Exposure of vitamin C sample to Oxygen	The broccoli sample aliquot was exposed to the oxygen that was present in the surrounding air for different amounts of time. Because the times of the various titration trials were not the same, the samples were oxidized to different degrees, which reduced the overall quality of the data that was collected. Ascorbic acid is known to be susceptible to oxidation and can be quickly and easily oxidized by oxygen. Additionally, this resulted in systematic error because each broccoli aliquot sample had a different level of oxidation because the sample was exposed to oxygen for various amounts of time.	This error cannot be completely eliminated due to the presence of oxygen in the atmosphere, but it can be greatly reduced. To achieve this, the sample must be prepared just prior to the titration test, and the bottle containing the aliquot must be sealed airtight.

Extension

My research on broccoli can be extended by swapping out the independent variable for something else, like microwave or cooking time. This can help in the discovery of further correlations between factors, leading to conclusions about the optimal method of consuming vitamin C-rich fruits or vegetables.

Bibliography

- familyeducation.com. (2017, August 2). *Why Fruits and Vegetables Are Important*. FamilyEducation. https://www.familyeducation.com/life/general-nutrition/why-fruits-vegetables-are-important
- Igwemmar, N. C., Kolawole, S. A., & Imran, I. A. (2013, November). *Effect Of Heating on Vitamin C Content of Some Selected Vegetables*. ijstr.org. https://www.ijstr.org/final-print/nov2013/Effect-Of-Heating-On-Vitamin-C-Content-Of-Some-Selected-Vegetables.pdf
- Chowdhury, Mohammed. (2016). *Determination of amount of Vitamin C (Ascorbic Acid) from supplied commercial tablets by using Iodometric titration*. Determination of Amount of Vitamin C (Ascorbic Acid) From Supplied Commercial Tablets by Using Iodometric Titration. https://www.researchgate.net/figure/Chemical-structure-of-vitamin-C_fig1_297438049
- University of Canterbury. (2016). *Determination of Vitamin C Concentration by Titration*. Retrieved November 18, 2022, from https://www.canterbury.ac.nz/media/documents/science-outreach/vitaminc_iodine.pdf
- John Olson. (n.d.). *Discrepant Event*. csun.edu. Retrieved November 18, 2022, from http://www.csun.edu/%7Ejco69120/coursework/695c/discrepant/index.html#:%7E:text=When%20ascorbic%20acid%20reacts%20with,and%20iodide%20ion%20are%20formed.
- harvard.edu. (2021, May 27). *Vitamin C*. The Nutrition Source. https://www.hsph.harvard.edu/nutritionsource/vitamin-c/#:%7E:text=Vitamin%20C%20can%20be%20destroyed,the%20liquids%20are%20not%20eaten.
- *NCBI -Diagnostic*. (2022). Retrieved November 18, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6049644/