Kinetic Study of the Copper ascorbic acid system

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Introduction

Vitamin C intake is linked to multiple potential benefits in biological functions. Thus, vitamin C is regarded as the most important hydrophilic antioxidant[1]. As an antioxidant vitamin C reacts with free radicals formed through metabolic reactions to prevent them from causing damage to tissue and cells thus reducing oxidative stress[2,3]. Copper is a transition metal that is required in the body for adequate growth, and lung elasticity and aids in the absorption of iron in the diet[4] However excess copper can result in the formation of hydroxyl radicals that can cause severe tissue and cell damage through the generation of hydroxyl radicals[5,6] for this reason copper is only required in small concentrations in the body. This research investigates the effect of copper on ascorbic acid degradation to provide insight into the hydroxyl radicals generated by the copper in the solution.

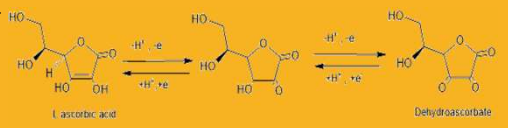


Figure 1: *oxidation of L ascorbic acid* (on left) to *dehydroascorbate* (on right)

Objectives/research questions

- How does pH affect the stability of ascorbic acid
- What is the effect of copper concentration on ascorbic acid by analysing the absorbance?
- Investigating the degradation of benzoic acid in the presence of ascorbic acid and copper at different pH

Experimental materials / results

1. L – ascorbic acid **2.** Copper II sulphate
3. 0.1M NaOH **4.** Na_2HPO_4 and KH_2PO_4
5. Hach hydrogen peroxide analyser kit **6.** Benzoic acid
7. Deionised water **8.** UV-Vis spectrometer
9. Dissolved oxygen probe

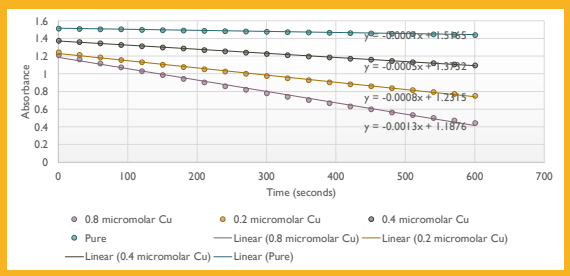


Figure 2: Degradation of ascorbic acid in deionised water at pH 5 in different concentration of copper II sulphate

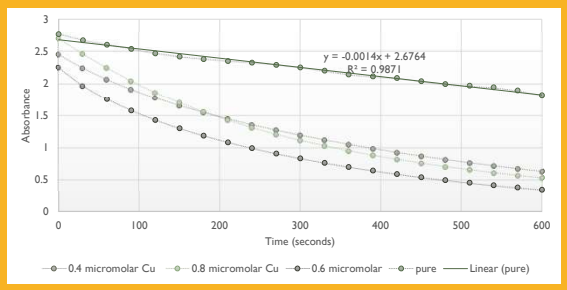


Figure 3: Degradation of ascorbic acid in phosphate buffer at pH 8.04 in different concentration of copper II sulphate

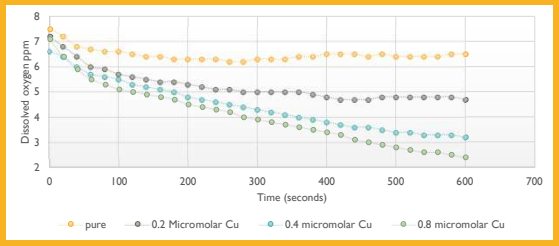
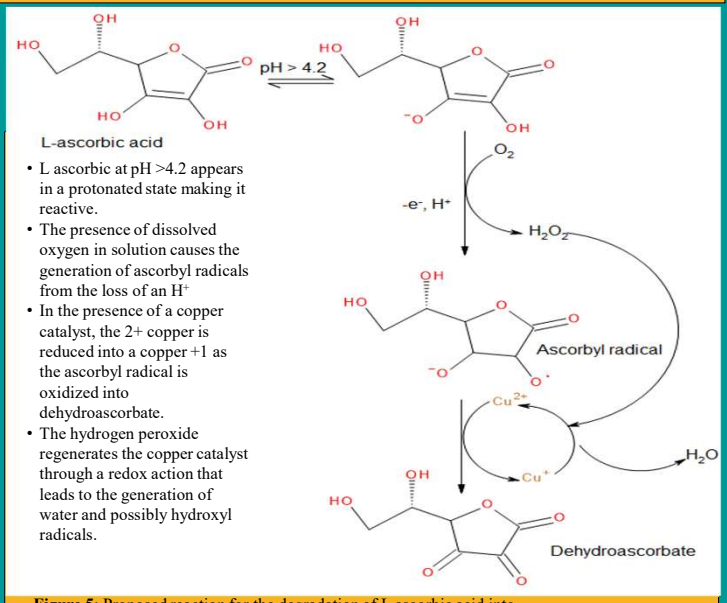


Figure 4: Graph of dissolved oxygen changes in the ascorbic acid solutions as the copper concentration changes in pH *5*



- L ascorbic at pH >4.2 appears in a protonated state making it reactive.
- The presence of dissolved oxygen in solution causes the generation of ascorbyl radicals from the loss of an H^+
- In the presence of a copper catalyst, the 2+ copper is reduced into a copper +1 as the ascorbyl radical is oxidized into dehydroascorbate.
- The hydrogen peroxide regenerates the copper catalyst through a redox action that leads to the generation of water and possibly hydroxyl radicals.

Figure 5: Proposed reaction for the degradation of L ascorbic acid into dehydroascorbate.

Figure 6 Hach hydrogen peroxide analysis

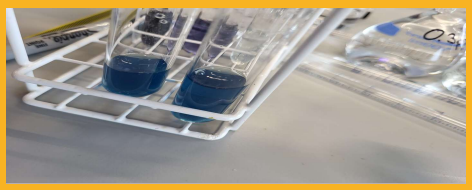


Figure 7: Hach Hydrogen peroxide analysis in the presence of ascorbic acid.

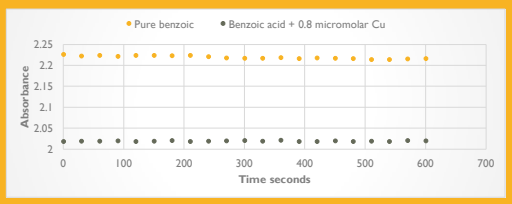


Figure 8: Kinetic study of benzoic acid in the absence of ascorbic acid.

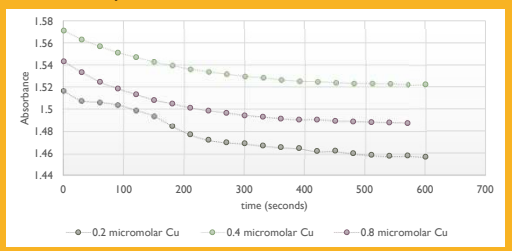


Figure 9: Degradation of Benzoic acid in the presence of 1mM ascorbic acid.

Conclusions

•Ascorbic acid degrades faster at higher pH and higher concentrations of copper in the solution.
•Ascorbic acid utilizes the dissolved oxygen in the solution to generate the hydrogen peroxide.
•Hydrogen peroxide gets broken down into hydroxyl radicals that react with benzoic acid.
•Benzoic acid degradation is only affected by ascorbic acid concentration. Benzoic acid doesn't degrade in the presence of copper. Thus only hydroxyl radicals can result in the degradation.
•Too much ascorbic acid in the solution inhibits the degradation of benzoic acid since ascorbic acid can also react with H_2O_2 and OH radicals.

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References

1. Office of Dietary Supplements - Vitamin C, https://ods.od.nih.gov/factsheets/VitaminC-HealthProfessional/#:~:text=Citrus%20fruits%2C%20tomatoes%20and%20tomato, (accessed 25 Sep 2023). **2.** R. Ahmad, *Free Radicals, Antioxidants and Diseases*, BoD – Books on Demand, 2018.
3. G. Pizzino, N. Irrera, M. Cucinotta, G. Pallio, F. Mannino, V. Arcoraci, F. Squadrito, D. Altavilla and A. Bitto, *Oxidative Medicine and Cellular Longevity*, 2017, **2017**, 1–13.. **4.** T. L. de Jager, A. E. Cockrell and S. S. Du Plessis, *Advances in Experimental Medicine and Biology*, 2017, **996**, 15–23.
5. in Drinking, Physiological Role of Copper, https://www.ncbi.nlm.nih.gov/books/NBK225407/, (accessed 25 Sep 2023). **6.** N. Husain and R. Mahmood, *Environmental Science and Pollution Research International*, 2019, **26**, 20654–20668.
More references are available in the thesis.