SHORT REPORT

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Enhancing iron(III) solubility using cassava and arrowroot starch

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ABSTRACT: Iron(III) is sparsely soluble in aqueous solutions even in an acidic condition. The solubility of iron(III) can be enhanced by complexing it with saccharides. Iron-dextran and iron-sucrose have been used to treat iron-deficiency anaemia. This work investigates the enhancement of the solubility of iron(III) in aqueous solution by complexing it with polysaccharides from locally available starch. Iron(III) was complexed with cassava and arrowroot starch and the state of iron(III) in the solutions was examined by UV-Vis spectrophotometry. The results showed that the solubility of iron(III) could be enhanced by cassava and arrowroot starch. It was asserted that these polysaccharides prevent the hydrolysis and precipitation of the iron(III) as iron-oxide. These finding might lead to an alternative treatment for iron-deficiency anaemia.

KEYWORDS: iron-starch, iron-saccharide, iron oxide

INTRODUCTION

Iron is a vital element for metabolic processes in organisms. Even though it is the fourth most abundant element on Earth, iron deficiency is one of the most common nutritional problems found in many countries. The problem is due to the low solubility of iron(III) (K_{sp} of $Fe(OH)_3 = 2.79 \times 10^{-39}$)[1] in aqueous solution leading to the low absorption of iron by the body. Iron(II) is more soluble in aqueous solutions than iron(III) but it is readily oxidized by oxygen in the air. Iron(III) interacts with polysaccharides to enhance the solubility or to form water-soluble compounds which are widely used in the treatment of iron deficiency anaemia[2–5]. Imferon, Fe(III)-dextran, is a sample used for parenteral therapy[6–9]. In addition, Fe(III)-polysaccharide interactions have proved to be useful for several industrial applications such as flotation and wastewater treatment[10]. This work studies the solubility enhancement of iron(III) by local starch (cassava and arrowroot starch) by determining the iron(III) dissolved in the aqueous solutions by UV-Vis spectrophotometry.

MATERIALS AND METHODS

Iron-cassava starch (Fe-CS) and iron-arrowroot starch (Fe-AS) were prepared according to our previous report[11]. Iron-dextran (Fe-DX), iron-sucrose (Fe-SU), and iron-oxide were prepared in this study for comparison. To prepare the iron-saccharide complexes, Fe-CS, Fe-AS, Fe-DX, and FE-SU, aqueous starch suspension (starch from local market), or sucrose (local market), or dextran (MW 15 000–20 000, Fluka) solution (saccharide 100 mg in 50 ml of distilled water) was heated at 90 °C until the mixture was clear. Then 1 ml of 5 M NaOH was added into the mixture. A solution of 0.01 M $FeCl_3$ (Merck, Germany) was prepared by adding 90 mg of $FeCl_3$ (0.55 mmol) in 50 ml of distilled water. Then, the $FeCl_3$ solution was added into the hot mixture which was vigorously stirred and heated to 90 °C for 10 min. A pH of 12 for the mixture was obtained. The mixture was then filtered (using a Whatman filter paper no. 1) and the filtrate was kept for further analysis. To prepare iron oxide, a solution of 0.05 M of $FeCl_3$ was prepared by adding 90 mg of $FeCl_3$ (0.55 mmol) into 100 ml of distilled water. Then 1 ml of 5 M NaOH was added into the solution which was vigorously stirred and heated for 10 min. A pH of 12 for the solution was obtained. The precipitate was then filtered off and the filtrate was kept for further analysis.

The solubility of iron(III) in the filtrate was determined by UV-Vis spectrophotometry using a Spectronic 20 UV-Vis spectrophotometer. Dilution of the

filtrate was needed if the iron(III) solution was too concentrated. All iron species in the solution were dissolved by adding 1 ml of 6 M HCl to 10 ml of the filtrate. After the reaction mixture was heated for 5 min, 1 ml of 0.5 M KSCN was added into 4 ml of the sample and the concentration of iron(III) was subsequently determined by UV-Vis spectrophotometry at 447 nm (the molar extinction coefficient of $Fe(SCN)^{2+}$ = 5×10^3 l cm^{-1}mol^{-1} at this wavelength [12]).

RESULTS AND DISCUSSION

For this study, iron-sucrose and iron-dextran were chosen because they have been used for iron-deficiency anaemia. Iron oxide was chosen as a reference. Iron(III) and the corresponding saccharide were mixed in a basic condition (pH 12) and then the solution or suspension was filtered. The filtrate obtained from iron oxide was colourless indicating the sparse solubility of iron(III) in water. The filtrate of iron-sucrose was pale yellow. In contrast, the colour of filtrates obtained from iron-cassava starch, iron-arrowroot starch, or iron-dextran were orange, red, and brown, respectively. The measured absorbances of the iron(III) solutions of iron oxide and iron-sucrose samples were lower than our detection limit, indicating that the concentration of iron(III) of both samples was less than 1 ppm. It was not surprising that the concentration of iron(III) in the iron oxide sample was very low ($K_{\rm sp}$ of $Fe(OH)_3$ is 2.79×10^{-39}). However, it was surprising that the concentration of the iron(III) solution in the iron-sucrose sample was very low. It was probably that unidentified species in sucrose accelerated the hydrolysis of iron oxide species leading to the precipitation of iron(III). The concentrations of iron(III) in the iron-cassava starch (28 ppm), iron-arrowroot starch (42 ppm), and iron-dextran samples (53 ppm) could be apparently measurable which is consistent with the vivid colours of iron(III) in the solutions. It was concluded that cassava and arrowroot starch and dextran were able to stabilize iron(III) and enhance its solubility in the aqueous solution by providing multiple hydroxyl groups to bind to the surface of iron oxyhydroxide to prevent further hydrolysis and precipitation [3]. The local structures of iron-polysaccharides will be needed to explain this phenomenon.

CONCLUSIONS

The solubility of iron(III) in an aqueous solution can be successfully enhanced by complexing to cassava and arrowroot starch. These polysaccharides prevent the hydrolysis and precipitation of the iron(III) hydroxide. There is a potential application to use those compounds as an alternative treatment for iron-deficiency anaemia.

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REFERENCES

1. Lide DR (2008) *Handbook of Chemistry and Physics*, CRC Press.
2. Ferrari E, Saladini M (2004) Iron(III) complexing ability of carbohydrate derivatives. *J Inorg Biochem* **98**, 1002–8.
3. Gyurcsik B, Nagy L (2000) Carbohydrates as ligands: Coordination equilibria and structure of the metal complexes. *Coord Chem Rev* **203**, 81–149.
4. Sipos P, Pierre TGS, Tombacz E, Webb J (1995) Rod-like iron(III) oxyhydroxide particles in iron(III)-polysaccharide solutions. *J Inorg Biochem* **58**, 129–38.
5. Laurent S, Forge D, Port M, Roch A, Robic C, Elst LV, Muller RN (2008) Magnetic iron oxide nanoparticles: Synthesis, stabilization, vectorization, physicochemical characterizations, and biological applications. *Chem Rev* **108**, 2064–110.
6. Coe EM, Bereman RD, Monte WT (1995) An investigation into the size of an iron dextran complex. *J Inorg Biochem* **60**, 149–53.
7. Lázaro FJ, Larrea A, Abadía AR (2003) Magnetostructural study of iron-dextran. *J Magn Magn Mater* **257**, 346–54.
8. London E (2004) The molecular formula and proposed structure of the iron-dextran complex, IMFERON. *J Pharmaceut Sci* **93**, 1838–46.
9. Ricketts CR, Cox JSG, Fitzmaurice C, Moss GF (1965) The iron dextran complex. *Nature* **208**, 237–9.
10. Pavlovic S, Brandao PRG (2003) Adsorption of starch, amylose, amylopectin and glucose monomer and their effect on the flotation of hematite and quartz. *Miner Eng* **16**, 1117–22.
11. Somsook E, Hinsin D, Buakhrong P, Teanchai R, Mophan N, Pohmakotr M, Shiowatana J (2005) Interactions between iron(III) and sucrose, dextran, or starch in complexes. *Carbohydr Polymer* **61**, 281–7.
12. MacCarthy P, Hill ZD (1986) Novel approach to Job's method: An undergraduate experiment. *J Chem Educ* **63**, 162–7.