

Ascorbic acid mediated iron mobilization from magnetic nanoparticles at higher temperatures

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The reaction between insoluble Fe(III) in magnetic nanoparticles and L-ascorbic acid in an aqueous solution was followed through UV-Vis spectroscopy. An exponential increase of water soluble Fe(II) was observed in a reaction mixture at higher temperatures. These results suggest possible harmful effects of widely used magnetic nanoparticles as a MRI contrast agents in combination with overload of organism with ascorbic acid in some specific conditions, like fever of patient. On the other hand, it may partly explain anticancer effects of high doses of ascorbic acid known for a long time in the treatment of some tumours.

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1. Introduction

Magnetic nanoparticles or ferrofluids are stable colloidal suspension superparamagnetic particles, usually from magnetite Fe_3O_4 , typically of order 10 nm diameter, immersed in a carrier fluid. Magnetic nanoparticles for cancer therapy and diagnosis are at the leading edge of the rapidly developing field of bionanotechnology [1-8].

There is a difference between water soluble Fe^{2+} compounds and generally water insoluble Fe^{3+} compounds. The latter are only water soluble in strongly acidic solutions, but water solubility increases when these are reduced to Fe^{2+} under certain conditions. When high concentrations of iron are absorbed, for example by haemochromatose patients, iron is stored in the pancreas, the liver, the spleen and the heart [9]. This may damage these vital organs. In a term of use magnetic nanoparticles in therapeutic application we have investigated interaction of colloid magnetic fluid and L-ascorbic acid as a reducing agent being a donor of two H^+ and two e^- .

2. Experimental procedure

2.1 Materials

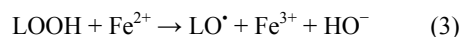
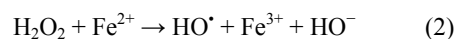
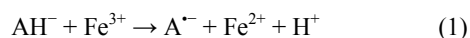
Solution of 0.5 mM L-ascorbic acid (H_2A) from Sigma was freshly prepared for each experiment in redistilled water. Water based magnetic nanoparticles Trans MAG-C of density 10 mg.ml^{-1} and particle size 30 nm obtained from Chemically GmbH (Berlin, Germany) was used with concentration of 0.3 mg.ml^{-1} after being diluted in redistilled water.

2.2 Measurements

For spectrophotometric and kinetic experiments was used spectrophotometer UVmini 1240 (Shimadzu, Japan). Experiments were performed by varying the initial temperature. Required temperatures of samples were kept by thermostatic bath ($\pm 0.1^\circ\text{C}$). Each of the kinetic runs was started by mixing solutions of ascorbic acid with magnetic nanoparticles (1:1) and the resulting solution complex was subjected to the spectral studies. Rate of reaction was determined by measuring the change in absorbance during reduction of magnetic nanoparticles by ascorbic acid, by monitoring the peak $\lambda_{\text{max}} = 265 \text{ nm}$.

3. Results and discussion

Since its discovery 80 years ago, ascorbic acid (vitamin C) has been one of the most popular chemicals whose beneficial effects are almost universally recognized. Ascorbic acid has antioxidant activity when it reduces oxidizing substances such as hydrogen peroxide, however, it can also reduce metal ions which leads to the generation of free radicals through the Fenton reaction. Upon their reduction by ascorbate (1), these metal ions can react with hydrogen peroxide (2) or lipid hydroperoxides (3) to produce either hydroxyl radicals or lipid alkoxyl radicals.



The metal ion in this reaction can be reduced, oxidized, and then again reduced in a process called redox cycling that can generate reactive oxygen species. The reactions between ascorbate and transition metals are thought to be responsible for the pro-oxidant and cytotoxic properties of ascorbate. Absorption spectra of L-ascorbic acid and magnetic nanoparticles are plotted in UV range in Figs. 1 and 2.

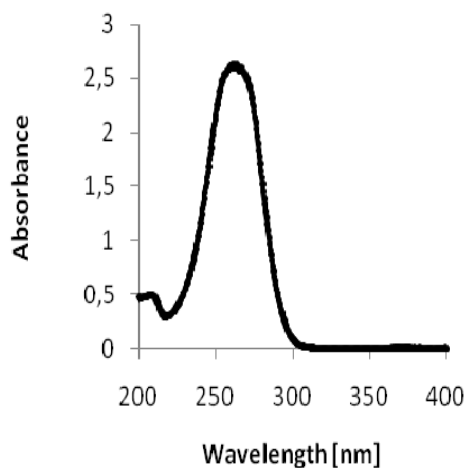


Fig. 1. Absorption spectra of 0.5 mM L-ascorbic acid in redistilled water in UV range.

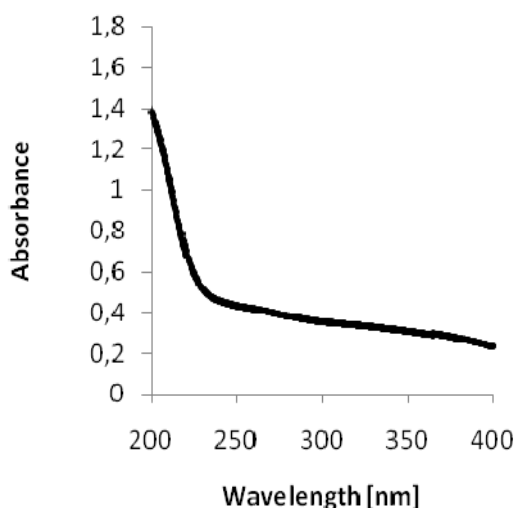
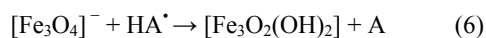
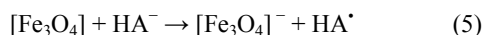


Fig. 2. Absorption spectra of magnetic nanoparticles with concentration of 0.3 mg/ml in redistilled water.

In these experiments we take to used of attribute ascorbic acid to reduced Fe(III) to Fe(II) during interaction [10-11]. Iron contained in magnetic nanoparticles is ranked among transition metal. Interaction is being in progress in two steps:



The oxidation of H_2A involves electron transfer from L-ascorbic acid to magnetic nanoparticles. H_2A first dissociated to HA^- and release a proton. Iron in magnetic nanoparticles reacts with HA^- involving an outer sphere one-electron transfer from HA^- to magnetic nanoparticles to form an intermediate reduced species $[\text{Fe}_3\text{O}_4]^-$ and ascorbate radical $\text{HA}^\bullet$. A rapid electron transfer from $\text{HA}^\bullet$ to $[\text{Fe}_3\text{O}_4]^-$ gives the reduced magnetic nanoparticles $[\text{Fe}_3\text{O}_2(\text{OH})_2]$ and dehydroascorbic acid A. This interaction we monitoring on spectrophotometer from the amount of L-ascorbic acid consumed in the reaction at its characteristic band - 265 nm.

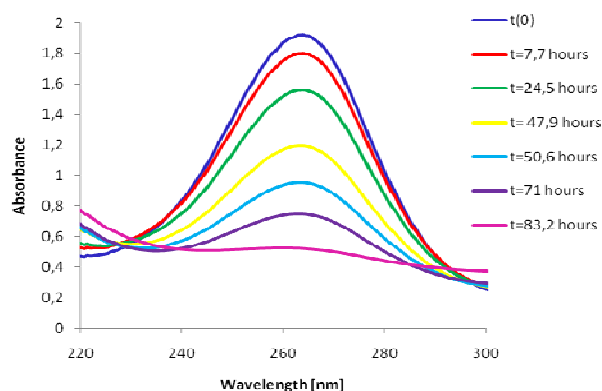


Fig. 3. Absorbance dependence of magnetic nanoparticles and L-ascorbic acid solution (1:1) in UV range during the mutual reaction at 20 °C.

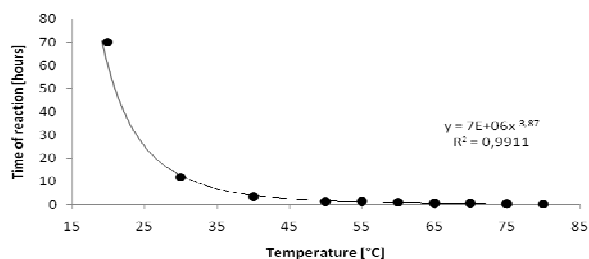


Fig. 4. Dependence of reaction time on the temperature of reaction complex.

From the plot (Fig. 3) we can see that the absorption peak of reactive mixture was on the decrease with time. The response time at room temperature 20 °C was 83 hours. The measurements were repeated at temperatures of samples: 30, 40, 50, 55, 60, 65, 70 and 75 °C kept at constant temperature by thermostatic water bath. With increasing temperature of samples, time of reduction of iron in magnetic nanoparticles was decreasing (Fig. 4). At 40 °C it was 175 min, 60 °C (65 min.), 70 °C (22 min).

3. Conclusions

The observed data reveals mechanism of possible harmful effects of widely used magnetic nanoparticles, e.g. as a MRI contrast agents in combination with overload of organism with ascorbic acid in some specific conditions,

like fever of patient. On the other hand, it may partly explain anticancer effects of high doses of ascorbic acid known for a long time in the treatment of some tumours [12].

Acknowledgments

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