Impact Of Different Concentrations Of L-Ascorbic Acid On The Particle Size Of Copper Nanoparticles

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ABSTRACT

Compared to traditional chemical reducing agents, L-ascorbic acid is better for the environment since it can convert copper ions (Cu^{2+}) to copper nanoparticles (Cu^0) under mild conditions. Its effectiveness stems from the fact that it facilitates the manufacture of small, uniform nanoparticles via its remarkable reduction power. In the colloidal solution, L-ascorbic acid serves as both a capping agent and a stabilizing agent, preventing nanoparticle aggregation. With respect to the size of CuNPs, the quantity of L-ascorbic acid is crucial. As mentioned in the paper, copper nanoparticles (Cunps) were created in an aqueous medium with the help of L-ascorbic acid, which served as both a reducing and capacitating agent. The purpose of the research was to determine the effect of different amounts of L-ascorbic acid on the size of Cunps particles. Two spectrophotometers, one for visible light and one for far infrared, were used to examine the constructed Cunps. Findings show that increasing the quantity of L-ascorbic acid causes a decrease in copper nanoparticle size.

Keywords: Copper, Ascorbic acid, Capping, Size, Nanoparticle.

I. INTRODUCTION

Among the most exciting new areas of study, nanotechnology is having a profound impact on several sectors, including healthcare, electronics, power generation, and materials science. Metal nanoparticles, one kind of nanomaterial, have recently attracted a lot of interest because of their distinct physicochemical characteristics compared to those of bulk metal. Due to its possible uses in catalysis, antimicrobial agents, electronics, and conductive inks, copper nanoparticles (CuNPs) have sparked a lot of interest in the field of study. (J. Suárez Cerda, et al., 2017) The enormous variety of technological applications made possible by their exceptional qualities, including high thermal and electrical conductivity, magnetic properties, and plasmonic characteristics, is really astounding. The functional characteristics of CuNPs are strongly impacted by their size and shape, making it difficult to synthesize CuNPs with precise control over these parameters. The concentration of reducing agents used during nanoparticle formation is one of the critical elements that dictates their size and shape. Copper nanoparticles, among others, are synthesized using L-ascorbic acid (vitamin C) as a reducing agent because of its moderate reducing power and capacity to give electrons. (S. Chandra, et al., 2014)

Copper sulfate and copper nitrate are common copper salts that are reduced in the presence of a reducing agent during the manufacture of copper nanoparticles. The nucleation and growth processes of the nanoparticles are greatly affected by the choice and concentration of the reducing agent. Because of its antioxidant characteristics, L-ascorbic acid has found extensive use as an environmentally friendly reducing agent in CuNP production. Nanoparticles may be more easily formed when it donates electrons to metal ions, reducing them to a metallic state. The rate of nucleation, particle development, and the final size of the nanoparticles are all impacted by the kinetics of the reduction process, which is in turn determined by the concentration of L-ascorbic acid. (A. P. Ingle, et al., 2014)

Reduced nucleation rate is caused by slower reduction of copper ions at lower concentrations of L-ascorbic acid. This causes a decrease in the number of nuclei produced, which in turn permits the current nuclei to enlarge into bigger particles. In such a situation, bigger copper nanoparticles with more uniform sizes tend to develop. However, the nucleation rate increases as the concentration of L-ascorbic acid rises since it speeds up the reduction process. The creation of smaller nanoparticles is facilitated by the quick synthesis of a greater number of nuclei. Nanoparticles with a narrower size distribution are produced when several nuclei quickly consume copper ions, which restricts the development of individual particles. To adapt the size of CuNPs and their characteristics to particular applications, it is important to adjust the concentration of L-ascorbic acid, a fundamental parameter. (R. Varshney, et al., 2010)

The biological, chemical, and physical characteristics of copper nanoparticles are greatly affected by their particle size. For instance, in catalysis, smaller nanoparticles with a higher surface area to volume ratio prove to be more effective catalysts than their bigger siblings. This is due to the fact that smaller CuNPs are more effective catalysts due to the increased surface area, which offers more active sites for catalytic processes. The effectiveness of CuNPs in antibacterial applications is also highly dependent on their size. Nanoparticles with a smaller size have a stronger antibacterial effect because they are more likely to interact with the membranes of microbes. In addition, the creation of sophisticated electronic devices and sensors relies on the size of CuNPs since it impacts their electrical conductivity and plasmonic characteristics.

In addition to its activity as a reducing agent, L-ascorbic acid plays an additional role in the creation of copper nanoparticles. In addition to stabilizing the nanoparticles, it prevents them from agglomerating by acting as a capping agent. (P. K. Khanna, et al., 2009) The surface energy and growth direction of the nanoparticles may be affected by the interaction between L-ascorbic acid and their surface, which in turn affects their size and form. Because L-ascorbic acid reduces and stabilizes CuNPs, getting the right concentration of it during synthesis is key to getting the nanoparticles you want.

Using L-ascorbic acid as a reducing agent has many advantages, including positive effects on the environment and the economy. A safer and more environmentally friendly alternative to traditional chemical reducing agents is L-ascorbic acid, a naturally occurring, non-toxic, and biodegradable chemical. Synthesizing copper nanoparticles using L-ascorbic acid is in line with green chemistry principles, which support the creation of long-lasting and environmentally benign nanomaterials. (L. Jin, et al., 2008) When thinking about the environmental impact and cost-effectiveness of producing and selling CuNPs on a big scale, this is a very essential factor.

II. REVIEW OF LITERATURE

Ramos, Ana Rose et al., (2019) The majority of the precipitates were produced during the first twenty-four hours, according to a comparison of samples taken at various intervals. The time it took to add new yield to the bulk reduced. To prevent further oxidation, ascorbic acid acted as a capping agent in this case.

Gultekin, Demet et al., (2016) via peroxidase enzymes that were partially isolated from fig (Ficus carica), this work attempted to generate copper oxide nanoparticles (CuO NPs) via a green manufacturing approach. In our tests, we were able to successfully create copper (II) oxide nanoparticles using the green synthesis approach. UV-VIS spectroscopy was used in conjunction with SEM and XRD to characterize the CuO NPs that were obtained. The ideal conditions for green synthesis were found to be a pH of 8, a temperature of 25 oC, and a concentration of 1 mM CuCl2 for 30 minutes. Green synthesis with peroxidase enzymes yielded SEM and XRD findings indicating that the obtained CuO NPs were 50-120 nm in size. Then, we gauged the nanoparticles' antioxidant and antibacterial capabilities; the findings confirmed that CuO NPs exhibited dual antimicrobial and antioxidant properties.

Umer, Asim et al., (2014) According to the findings, the concentration of copper nanoparticles rose as the molar ratio of L-ascorbic acid increased. The typical size of copper nanoparticles was determined to be between 50 and 60 nanometers. No signs of sedimentation or separation were detected after three months of storage at room temperature and humidity. Because ascorbic acid is used, the technique is safe, economical, and eco-friendly.

Qingming, Liu et al., (2012) the aqueous solution reduction approach was used to create Cu nanoparticles by reducing Cu^{2+} ions with ascorbic acid. Researchers looked at how the creation of Cu nanoparticles was affected by the average size of Cu_2O particles and the pH of the solution. We created Cu particles at pH 3, 5, and 7, with pH 7 yielding the smallest Cu particles. Nevertheless, pH 9 and 11 were insufficient for the formation of Cu particles. Particle size distributions of Cu_2O and Cu may influence one another.

biçer, Mustafa & Şişman, İlkay. (2010) Copper nano/microstructures in various morphologies were synthesized at low temperatures using an environmentally friendly chemical process. These ascorbic acid-reductant and cetyltrimethylammonium bromide (CTAB)-capping synthesises achieved good yields in an aqueous solution.

III. MATERIALS AND METHODS

Serine, L-ascorbic acid (vitamin C), copper chloride dihydrate ($CuCl_2 \bullet 2H_2O$, 97% purity), and other analytical grade compounds were used. Without further processing, the remaining compounds used were of analytical quality. Throughout the investigation, double-distilled water was used.

Synthesis of copper nanoparticles

For copper nanoparticles, the first step in the one-step production process is to dissolve 0.02 mol/L of copper chloride dihydrate in deionized water. A blue solution is the outcome of this process. While being rapidly agitated at 353 K in an oil bath, the copper salt solution in water was progressively supplied with 0.1 mol/L of L-ascorbic acid. Through a series of intermediate stages, the dispersion's hue evolved from white to yellow to orange to brown to deep brown. The formation of yellow and subsequently orange hues indicates that small nanoscale copper particles were produced by ascorbic acid-assisted reduction. The next step was centrifuging the mixture for 15 minutes. The liquid on top eventually sank to the bottom after sitting at room temperature for two months. Various doses of ascorbic acid were tested in order to examine the size and shape of copper nanoparticles.

Characterization

A first assessment of the production of copper nanoparticles was conducted using a UV-Visible spectrophotometer that had a 1.0 cm path length and a spectral range of 200 nm to 800 nm. L-ascorbic acid bound to zero-valent copper particles, as shown by FTIR analysis.

IV. RESULTS AND DISCUSSION

Metal nanoparticles characterization

The peak location and morphologies are sensitive to particle size, making UV-Visible absorbance spectroscopy a particularly valuable tool for analyzing metal nanoparticles. Figures 1 and 2 show the results of recording the samples' UV-Visible spectra at various time intervals for each color change that occurred during the creation of copper nanoparticles in an aqueous solution.

Figure 1: Sample dispersion across various time durations

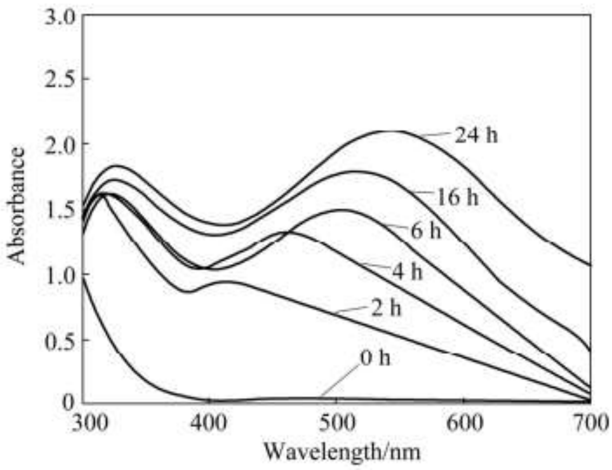

Figure 2: ultraviolet-visible spectra measured at various time periods

When L-ascorbic acid is added, the solution goes through a series of color changes, starting from colorless and progressing through yellow, orange, brown, and eventually dark brown. After this, it goes back to being colorless. After two hours of response, an absorption peak appears where none was before. Over time, the reaction intensified due to the formation of copper nanoparticles. After twenty-four hours, the synthesis was finished.

Figure 3 shows the effects of different concentrations of L-ascorbic acid on the UV-Visible absorbance spectra of the produced copper nanoparticles. The concentrations tested were 0.08, 0.09, and 0.10 mol/L. The first peak of the various curves, which corresponds to the oxidation product of L-ascorbic acid, was seen at 335 nm. An increase in the concentration of L-ascorbic acid causes the second absorption peak to shift toward the red end of the spectrum. The detection of an absorption peak at around 560 nm has provided irrefutable evidence of the presence of copper nanoparticles. The existence of tiny separated copper nanoparticles was suggested by the higher peak at this wavelength in the study's resultant copper nanoparticles.

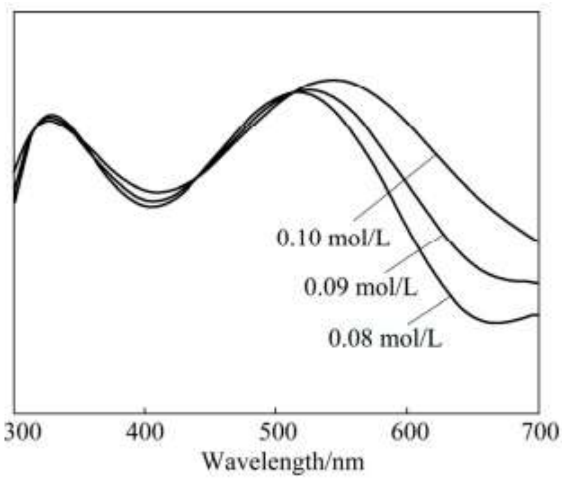

Figure 3: The UV-Visible Absorption Spectra of Copper Nanoparticles Stabilized with Different Concentrations of L-Ascorbic Acid

<u>Stability of copper nanoparticles</u>

One important aspect of nanoparticles is their capacity to remain dispersed in a solution. Without the use of any additional capping agent, L-ascorbic acid served as both the reducing and capping agent in this investigation. The images of the distribution both before and after the two months of storage may be seen in Figure 4.

Figure 4: Analysis of the dispersion of produced copper nanoparticles both immediately after synthesis and 2 months later

To keep copper nanoparticles from oxidizing during production, an excess of L-ascorbic acid is required.

Copper nanoparticles may be able to avoid aggregation due to the high concentration of hydroxyl groups, which aid complexation with the molecular matrix via inter- and intramolecular hydrogen bonding. The FTIR study's results, as shown in Figure 5, corroborate these conclusions.

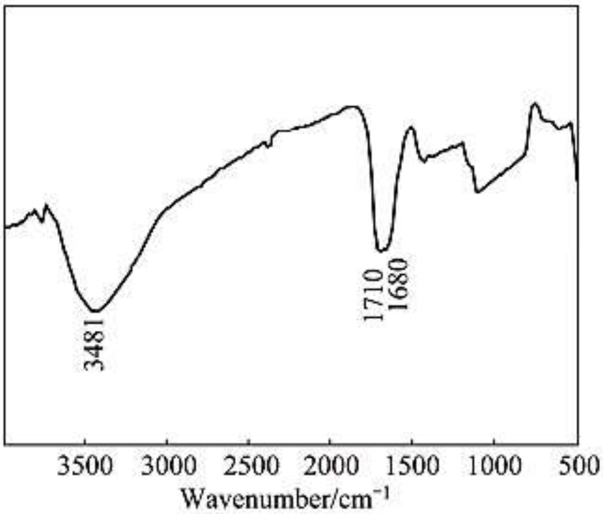

Figure 5: Analysis of the Fourier Transform infrared Absorption by L-Ascorbic Acid on Copper Nanoparticles

The peaks at 3481, 1710, and 1680 cm−1 are seen in the FTIR spectrum. The hydroxyl, oxidized ester, and conjugated carbonyl groups are denoted by these peaks, in that order. The findings show that the surface of the copper nanoparticles has a polyhydroxyl structure. Copper nanoparticles are dispersed very well by the polyhydroxyl structure. Hence, L-ascorbic acid does double duty as a copper nanoparticle antioxidant and reducing agent. That means an inert gas shield isn't necessary to finish the reaction.

V. CONCLUSION

In other words, larger particles are generated by lower concentrations of L-ascorbic acid, and smaller ones by higher ones; this relationship holds true for the size of the nanoparticles as well. The involvement of L-ascorbic acid in controlling the growth and nucleation processes of CuNP synthesis is thought to be responsible for this characteristic. Accelerated nucleation at higher concentrations results in an increase in the number of smaller nuclei, which in turn limits the expansion of the particles. Nanoparticles grow bigger at lower concentrations because nucleation is slowed and particle development is more noticeable. Finding the right nanoparticle size via precise concentration optimization of L-ascorbic acid is essential for adapting their characteristics to particular applications including catalysis, electronics, and antimicrobials, as highlighted in the paper.

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