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Original Research Article

Facile Green Synthesis of Copper Oxide Nanoparticles (CuO NPs) utilizing Passiflora caerulea L. Leaves Extract

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ABSTRACT

This article was performed to evaluate an eco-friendly and simple approach to synthesis copper oxide nanoparticle (CuO NPs). *Passiflora caerulea* leaf extract was used in the synthesis of CuO NPs as a reducing and stabilizing agent. The formation of CuO NPs was characterized by UV-Vis spectrum, Fourier Transform Infrared Spectroscopy (FT-IR), X-ray Powder Diffraction (XRD), and Scanning Electron Microscopic (SEM) analysis. Based on the results obtained from UV-Vis spectra, a potent resonance is observed at 280 nm. According to the FT-IR, distinct peaks of Cu-O stretching vibration positioned at 501.59 cm^{-1}, 590.53 cm^{-1} and 620.19 cm^{-1}. It was found that the particles had a rod-shaped and spherical morphology with a size of 19.15 to 38.15 nm based on SEM analysis. The structural characterization was performed utilizing XRD in line with reflections of the face-centered cubic (fcc) phase of the CuO NPs (111, 200, 220, and 400). The average particle size of NPs was found to be 29.35 nm by using XRD data and Scherrer equation. As a result of the unique characteristics and size of the synthesized nanoparticles, and the fact that the method used adheres to green chemistry principles and is completely safe and economical, it is clear that *Passiflora caerulea* leaf extract is capable of synthesizing such nanoparticles in a high capacity

Keywords: Biosynthesis; Copper oxide nanoparticles; Green chemistry; Leaf extract; Passiflora caerulea

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IntroductionThe emergence of a revolutionary field of science called nanotechnology is evident in various areas such as biomedicine, agriculture, mechanics, electronics, medicine, cosmetics, sensors, textiles, energy, and optics [1-4]. In 1974, professor Noria Taniguchi developed nanotechnology to fabricate materials at the level of a nanometer. "Nano" is applied to show one billionth of a meter or 9-10, which also means to dwarf (very tiny). Nanoparticles are remarkable for their century due to their mechanical, optical, and chemical attributes. Nanoparticles have altered properties such as morphology, distribution, and size that have improved them compared to larger particles of bulk material [5]. Many solutions based on environmental and technological issues in different fields, including water treatment, catalysis, medicine, conversion of solar energy, can be provided by nanoparticles. Among the heat transfer systems, we can mention CuO NPs, which have various applications of extremely strong materials, sensors, and catalysts. The methods such as electrochemical reduction, chemical reduction, thermal decomposition, heat dissolution reduction, and chemical vapor deposition have been used to synthesize metal nanoparticles, which fall into the category of chemical and physical methods. However, many problems with these methods are evident. These problems include high energy consumption, being environmentally friendly, using toxic solvents, and hazardous byproducts production [6]. Since the methods are earth-friendly, affordable, supportable, and outspoken, they are considered as a major reason to synthesize metallic nanoparticles of the various segments from plants [1]. Various procedures are achieved using sustainable chemistry principles. Sources such as microorganisms, animals, and plants can synthesize the nanoparticles. Decomposition, photocatalytic and antimicrobial activity, binding of DNA and sensors, cytotoxicity as an antioxidant, etc., are among the applications of plant extracts for copper-oriented nanoparticles [7-9]. We can replace these hazardous substances with biological synthesis or green synthesis, which uses plant extracts or microorganisms to produce nanoparticles. Decreasing agents such as plant metabolites, which stabilize the shape and size of the produced nanoparticles as a coating agent, are responsible for copper ions conversion to copper metal [10, 11]. The green synthesis method is an affordable, non-toxic and innovative method, used instead of synthetic and inorganic compounds to prepare nanoparticles. Passiflora caerulea L is rich in antioxidants, used more like a natural reducing and stabilizing agent than plant species [12]. This study evaluated the CuO NPs synthesis by extract of the *Passiflora caerulea* L leaves. Color variations and UV-Visible spectroscopy confirm and characterize the

synthesized nanoparticles, respectively. Potential biomolecules were identified by performing the spectral measurements of the FTIR. SEM observed the nanoparticles' size. XRD was used for structural characterization and subsequently inhibited the growth of bacteria that caused the disease. To the best of our knowledge, biosynthesis of CuO NPs, using *Passiflora caerulea* L. extract by easy and environmentally approaches for antibacterial activity effects have not been reported.

Experimental

Materials

Fresh Passiflora caerulea leaf (figure 1) was collected from Qom county in Qom province, Iran. The chemicals Copper (II) nitrate trihydrate, NaOH, and HCl were analytical grade and purchased from Merck®. To follow green chemistry principles, hazardous reagents were removed from the synthesis, and only water was used.

Figure 1. Fresh Passiflora caerulea leaf

Preparing plant extract

20 grams of fresh *Passiflora caerulea* L leaves were collected from the campus and used to prepare the extract. Fresh leaves were widely rinsed with faucet water, then two times rinsed with deionized water to remove sediment. Prepared leaves were dried for in shade. Then the leaves were poured into 100 ml of distilled water and heated. Following 15 minutes, a red solution appeared, which is the extract necessary for the synthesis of nanoparticle. With the use of Whatman grade No. 1 filter paper, the aqueous leaf extract was filtered. Afterward, the extract

obtained was kept at 4 degrees for further analysis and use.

Phyto-synthesis of CuO NPs

Copper ions (Cu^{2+}) are reduced by the plant extract used in this green synthesis. In order to synthesize CuO NPs, copper nitrate 1 mM solved in 250 ml distilled water and 20 ml of *Passiflora caerulea* L leaves extract was combined dropwise in a 500 CC beaker, while stirring continuously by magnetic stirrer. Upon adding the extract, the solution's color gradually changes from straw yellow to light green, indicating that CuO NPs are being formed (figure 2).

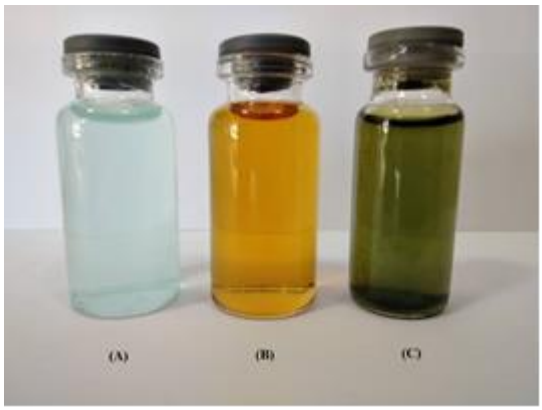

Figure 2. 1 mM Cu (NO3)2.3H2O solution (A), Passiflora caerulea L leaves extract (B), CuO NPs (C)

Using a centrifuge, we centrifuge the sediment for 10 minutes at a speed of 10000 while washing it with standard ethanol and distilled water. Once centrifuged, it is protected in an airless glass bottle and can also be used for XRD, FTIR, and SEM analysis.

Characterization of green synthesized CuO NPs

To analyze the UV-Vis spectroscopy, we use a physic-miniature UVS-2500 spectrophotometer. An ultraviolet absorption spectrophotometer with a resolution of 1 nm and a width of 190-1100 nm was used. The FT-IR spectrum was measured using a Jasco 6300 spectrometer. A Philips-PW1730 advanced diffractometer operating at 40 KV and 40 mA was used to obtain an X-ray powder diffraction (XRD) pattern. In order to determine particle size and morphology on the surface of the samples, scanning electron microscopy (SEM TESCAN MIRA3) was used.

Results and discussion

UV-vis spectroscopy

As shown in Figure 2, the reduction of copper ions to copper oxide nanoparticles was confirmed by UV-vis spectra (figure 3). As the spectrum exhibits, a sharp and intense peak at 280 nm appears, proving the CuO NPs presence in the sample. Higher adsorption indicates the increasing $Cu2^{+}$ conversion to copper as a nanoparticle leading to higher CuO NPs concentrations [13, 14].

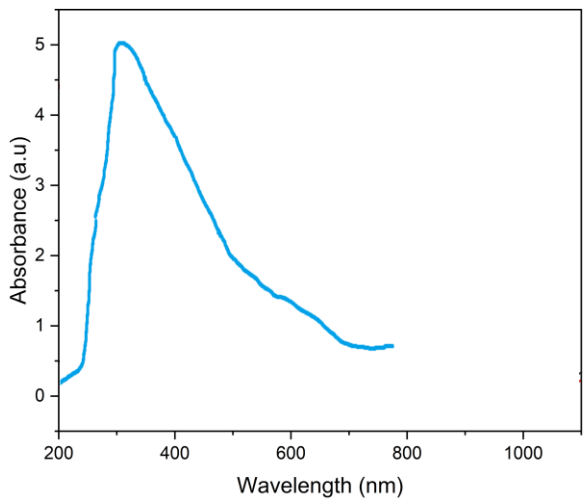

Figure 3. UV-Vis absorption spectra of CuO NPs using *Passiflora caerulea* L leaves extract

Fourier-transform infrared spectroscopy (FTIR)

Entity-related information along with extract functional group associated with Nanoparticle synthesis is provided by FTIR. The FTIR spectrum (figure 4) shows the environment-friendly CuO NPs green synthesis interceded by extract of the *Passiflora caerulea* L leaves. The broadest peak in the spectrum, at 3426.16 cm^{-1} in extract spectra and 3432.61 cm^{-1}, is equal to the stretching of O-H and (or) N-H in amino acids, phenols, and alcohols. The peak of 1622 cm^{-1} and 1628.28 cm^{-1} is associated with C=O tension in ketones. The deformation of the peak of 1383.29 cm^{-1} up to CH_2 & CH_3. The peak of 1622 cm^{-1} and 1628.28 cm^{-1} is related to C=C tension. Weak peaks at a distance of 511.34 to 779.50 cm^{-1} in extract spectra are related to C-Cl traction in the halo composition. Finally, three distinct peaks at 501.59 cm-1, 590.53 cm-1 and 620.19 cm-1 indicates the Cu-O stretching vibration bond. So, nanoparticles synthesized by metabolites and proteins such as terpenoids are surrounded by functional groups of alcohols, ketones, aldehydes, and carboxylic acids. Analysis of FTIR studies showed that they have a strong capacity in the

field of phenolic metal bonding. It is concluded that phenols may be formed from metal nanoparticles (e.g., copper nanoparticle caps) to prevent aggregation and thus stabilize the environment. Based on this, biological molecules can perform dual stabilization functions and CuO NPs formation in the aqueous medium [15].

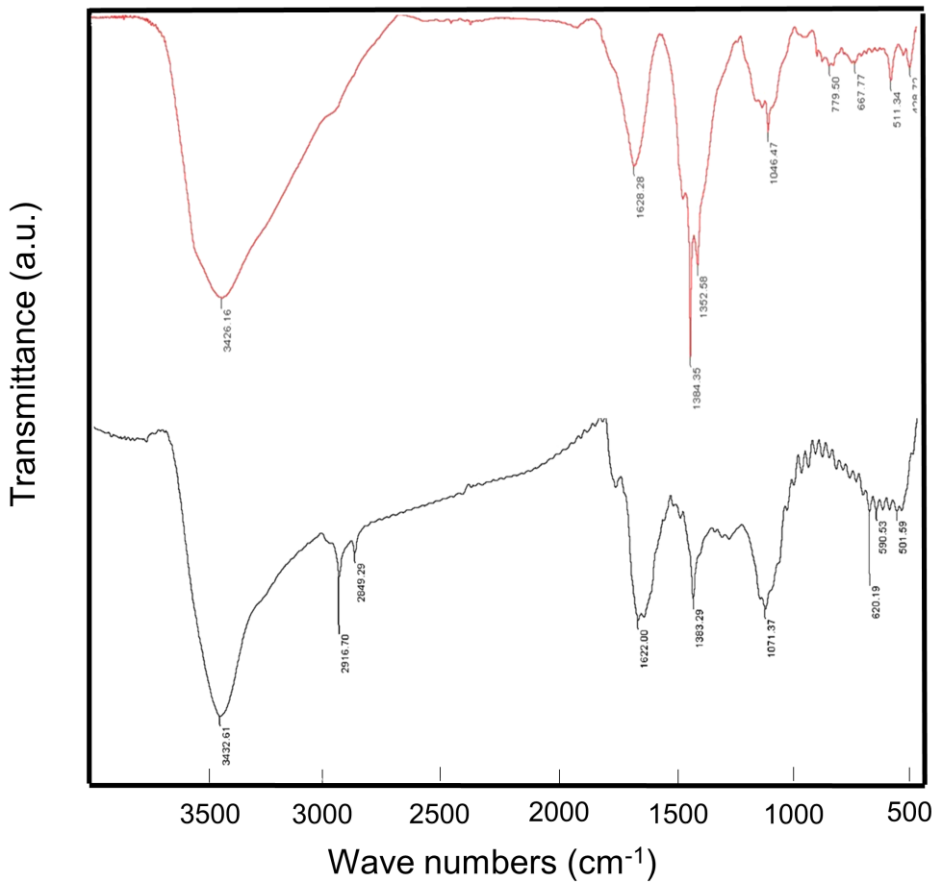

Figure 4. FTIR pattern of CuO NPs using Passiflora caerulea L leaves extract (black) FTIR pattern of Passiflora caerulea L leaves extract (red)

Scanning electron microscopy (SEM)

As shown in figure 5, the SEM image shows CuO NPs size and external morphology. According to the SEM image, the CuO NPs are rod-shaped and spherical. It indicates a range of particle sizes between 19.15 ±1.5 and 38.15 ±1.8 nm. During the formation of the nanoparticles, the synthesized particles adhere to each other as can be seen in the figure. It can be derived that nanoparticle stability and agglomeration may be affected by ecological factors [16]. The images obtained from these nanoparticles are consistent with the previous studies conducted by researchers, and this indicates the successful synthesis of these nanoparticles and the

effectiveness of *Passiflora caerulea* leaf extract in green synthesis [17-19].

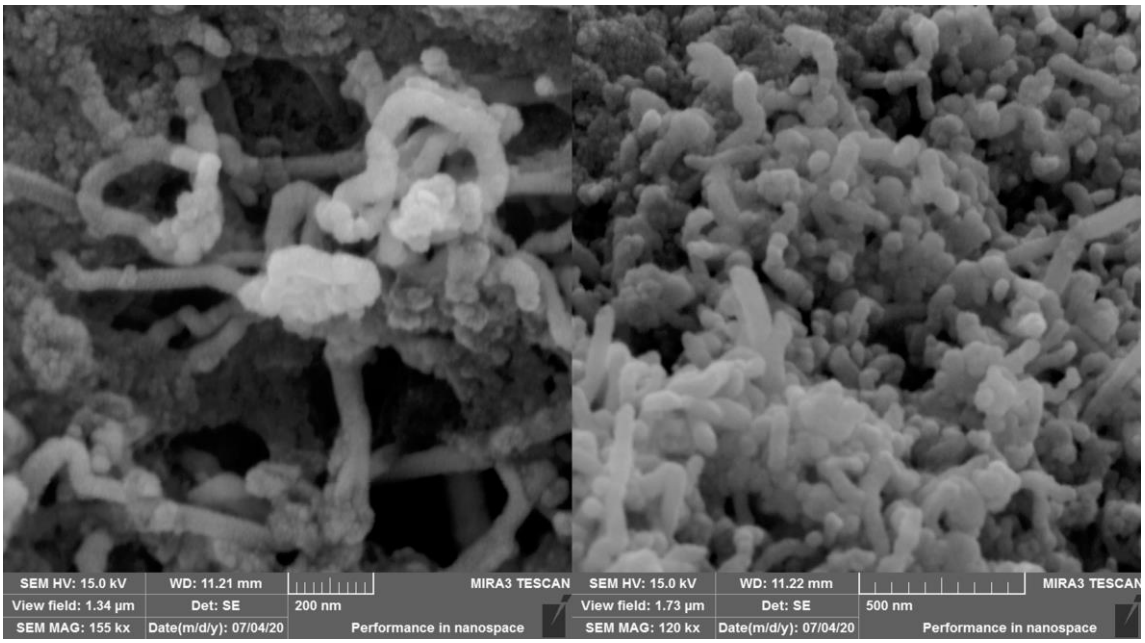

Figure 5. Scanning electron microscopy of CuO NPs synthesized by *Passiflora caerulea* leaf extract

X-ray Powder Diffraction (XRD)

The unique nature of the synthesized CuO NPs was confirmed by X-ray diffraction analysis. The three peaks in the diffraction pattern at angles of 27.85º, 49.78º and 59.63º are related to the JCPDS standard copper numbered 89-2838 [20]. Four notable peaks at 81.31º, 59.63º, 49.78º, and 27.85º (XRD pattern of biosynthesized CuO NPs) correspond to (400), (311), (200), and (111) reflections of the face-centered cubic phase (fcc) of CuO NPs, appeared. The aggregation of synthesized nanomaterials using *Passiflora caerulea* L leaf extract is due to their encapsulation with chemicals. Sheet layers create the aggregation of these organic parts. The only spectral disturbance is visible in the spectrum using X-ray diffraction (XRD) analysis. The average crystallite size of CuO NPs is estimated using Debye Scherrer formula [21], which is 29.35 nm.

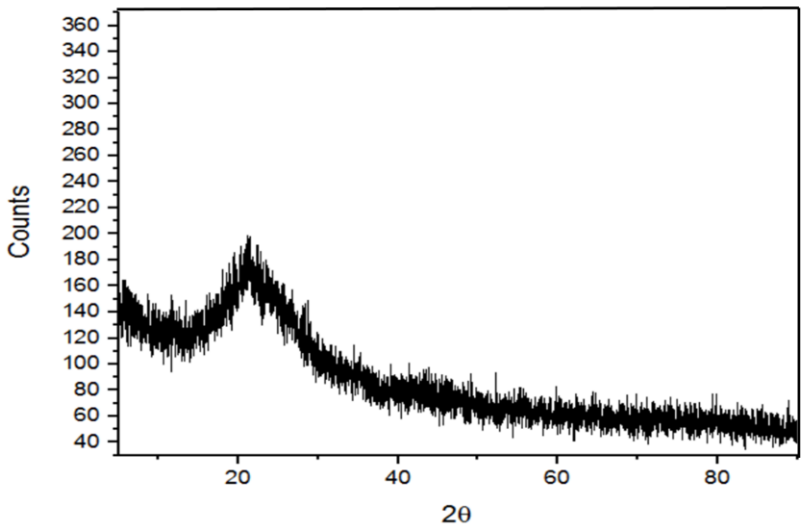

Figure 6. XRD pattern of biosynthesized CuO NPs

Conclusion

Using nanotechnology, phytochemistry and inorganic chemistry, we have developed safe, economical, reliable and environmentally friendly methods for synthesizing metal nanoparticles via the green route. We have developed a simple biological and cost-effective method for the preparation of stable CuO NPs using *Passiflora caerulea* L leaf extract as a reducing agent at low temperature. Through the use of XRD and SEM, we investigated the structural characteristics and morphology of the obtained CuO nanoparticles. The findings confirm the reduction of copper nitrate to CuO NPs with high stability and without any impurities. The formation of CuO NPs was also confirmed by the adsorption spectrum peak. Primary amines of proteins and phenols are factors for the stabilization, reduction, and capping of these nanoparticles (based on FT-IR). Based on FT-IR analysis, these nanoparticles are inhibited and reduced by primary amines of proteins and phenols to accumulate sheets and provide environmental stability. As a final note, based on the average size of nanoparticles, 29.35 nm based on Scherer's equation, along with the unique shape, it is possible to make use of these nanoparticles for a variety of applications, including their antibacterial, antioxidant, and catalytic effects.

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Conflicts of Interest

All authors declare that there is no conflict of interest.

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