

Phytofabrication and characterization of monodisperse copper oxide nanoparticles using *Albizia lebbek* leaf extract

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Abstract Simple effective and rapid approach for the green synthesis of copper oxide nanoparticles (CONPs) using of *Albizia lebbek* leaf extract was investigated in this study. Various instrumental techniques were adopted to characterize the synthesized CONPs, viz. UV–Vis spectroscopy, SEM, TEM, EDS and XRD. The synthesized CONPs were found to be spherical in shape and size less than 100 nm. It could be concluded that *A. lebbek* leaf extract can be used as a cheap and effective reducing agent for CONPs production in large scale.

Keywords Nanoparticles · Copper oxide · *Albizia lebbek* · Green synthesis · Electron microscopy

Introduction

Metal nanoparticles gained much interest in recent years in the nanotechnology field due to their remarkable properties such as optical, magnetic and catalytic activity (Bhattacharya and Gupta 2005). Metal nanoparticles finding promising applications in nanosensors, optoelectronics, nanodevices, absorbents, information storage, etc. (Harne et al. 2012). In literature, silver and gold nanoparticles are extensively studied because of their high conductivity and non-oxidizing nature but synthesis of copper and copper-based nanoparticles are limited (Abboud et al. 2014; Sankar et al. 2014; Gunalan et al. 2012; Lee et al. 2011). Copper oxide (CuO) nanoparticles are of

significant technological interest and have attracted more attention due to their high conductivity and low cost. CuO nanoparticles are used in superconductors, gas sensors, magneto resistance materials, lubricants, lithography, dye sensitized solar cells and nanostructure composites preparation (Li et al. 2008; Kruis et al. 1998; Cheon et al. 2012; Tarasov et al. 2002; Baik et al. 2000). Biological applications of CuO nanoparticles include as an antimicrobial, anti-fouling, anti-biotic, anti-fungal agent when added to textiles (Abramov et al. 2009) and also used as biocidal agent in pesticide production (De Oliveira-Filho et al. 2004). Copper oxide nanoparticles can be synthesized by various methods like electrochemical, sonochemical, chemical reduction, microwave irradiations, etc. (Mandke and Pathan 2012; Dang et al. 2011; Zhao et al. 2004). Use of toxic chemicals as reducing and capping agents in chemical synthesis restricts the use of CuO nanoparticles in biological applications and also discharge of wastes may lead to environmental pollution. With increasing awareness in green chemistry, the scientific community has been focused on development of eco-friendly and biocompatible nanoparticle synthesis methodologies (Tsibakhashvil et al. 2010). Microorganisms, plants and enzymes are employed as environmental benign materials for synthesis of biocompatible, non-toxic synthesis of metal nanoparticles (Abboud et al. 2014; Tsibakhashvil et al. 2010; Augustine et al. 2014; Vet-chinkina et al. 2014). Synthesis of metal nanoparticles using plant extracts was found valuable process as compared to microbes due to several advantages like simple process, easily available, safe to handle and easily scaled up (Kouvaris et al. 2012; Vanaja and Annadurai 2012). Reduction rate and stabilization of nanoparticles can be increased by the presence of various phytochemicals in plant extract which mediate the nanoparticle synthesis and

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can act as capping and reducing agents (Rashmi and Preeti 2009). Studies on biological synthesis of CONPs using plant are limited in the literature and no report is available for *Albizia lebbek* leaf extract. The present study attempts to utilize for the first time *A. lebbek* leaf extract as reducing agent to synthesis CONPs. Characterization of synthesized CONPs was done by UV–Vis spectroscopy, SEM, EDS and TEM analysis.

Experimental

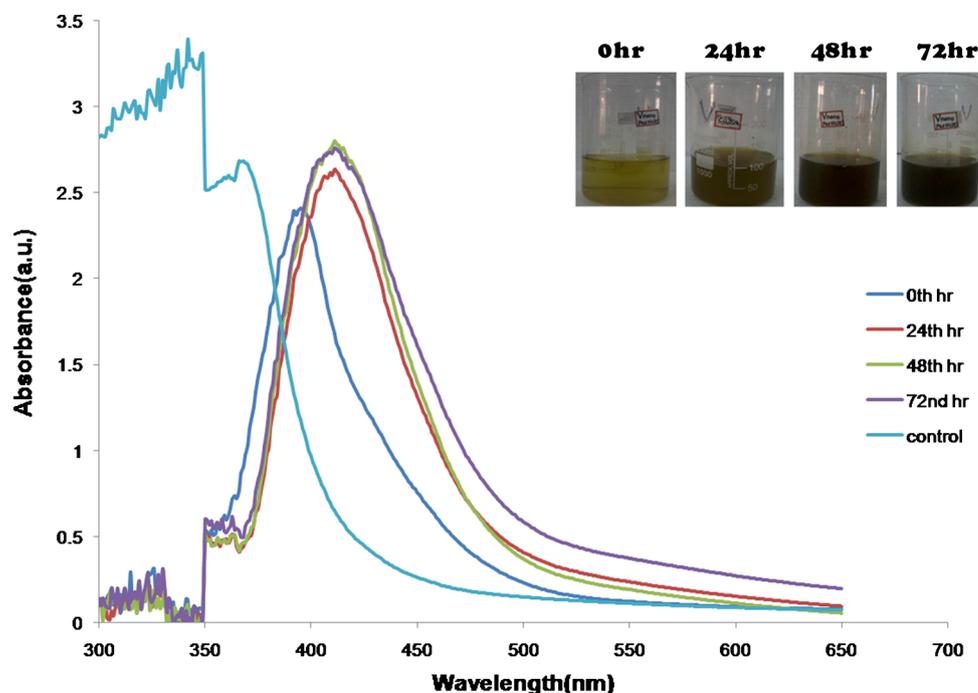
Preparation of *A. lebbek* aqueous leaf extract

Fresh leaves of *A. lebbek* were collected from Government College of Technology campus, Coimbatore. The leaves were surface cleaned with double distilled water, shade dried for a week and powdered using a kitchen blender. 5 g of leaf powder was mixed with 50 mL of double distilled water and kept in a water bath at 60 °C for 10 min. The extract was filtered by using Whatman No. 1 filter paper and stored at 4 °C for further use.

Green synthesis of CONPs

10 mL of *A. lebbek* aqueous extract was mixed with 90 mL of copper sulphate (1 mM) solution in an Erlenmeyer flask incubated in the dark at 37 °C for synthesis of CONPs. A control setup was also maintained without *A. lebbek* leaf extract. The formation of CONPs was confirmed by colour changes from pale yellow to brown.

Fig. 1 UV–Vis spectra of CONPs synthesized with *A. lebbek* leaf extract



Characterization of CONPs

UV–Vis spectroscopy analysis

The reaction progress for the formation of CONPs using *A. lebbek* leaf extract was monitored by visual colour change and UV–Vis spectral scanning. Surface plasmon resonance (SPR) of CONPs was characterized by using UV–Vis spectrophotometer (Hach DR 5000) at the resolution of 1 nm from 300 to 700 nm. The plant extract was used as control.

SEM and EDS analysis

The sample was prepared with a drop of colloidal solution of nano copper oxide on a carbon-coated copper grid and completely dried by vacuum desiccator. SEM (FEI Quanta 250, Czech Republic) instrument at accelerating voltage of 30 kV equipped with EDS was used.

TEM analysis

A drop of aqueous CONPs sample was loaded on the carbon-coated copper grid which was allowed to dry for an hour. The size and shape of CONPs from *A. lebbek* were determined from TEM images.

XRD analysis

CONPs were dried and the powdered sample was used for X-ray diffraction (XRD) analysis. The XRD analysis was

performed by X’Pert Pro A Analytical X-ray diffractometer using Cu K α radiation in the range of 10°–80° at 3 kW.

Results and discussion

In the present study, *A. lebbek* leaf extract was used as reducing agent for synthesis of CONPs. *A. lebbek* leaf extract was mixed with copper sulphate solution and the reaction mixture starts colour change after 24 h of incubation (Fig. 1). Colour change observed in the reaction

mixture confirmed the formation of CONPs. UV–Vis spectroscopy is a valuable tool to study the SPR of synthesized nanoparticles. The UV–Vis spectra of CONPs synthesized using *A. lebbek* showing absorption peak maxima at 413 nm and found to be characteristic peak of CONPs (Fig. 1). Colour change was due to the excitation of SPR of CONPs (Mulvaney 1996). According to Mei’s theory, the shape of the synthesized nanoparticle is spherical if a single sharp absorbance peak observed in the UV–Vis spectrum (Mie 1908), and in our study presence of the single peak confirmed that synthesized CONPs were spherical in shape.

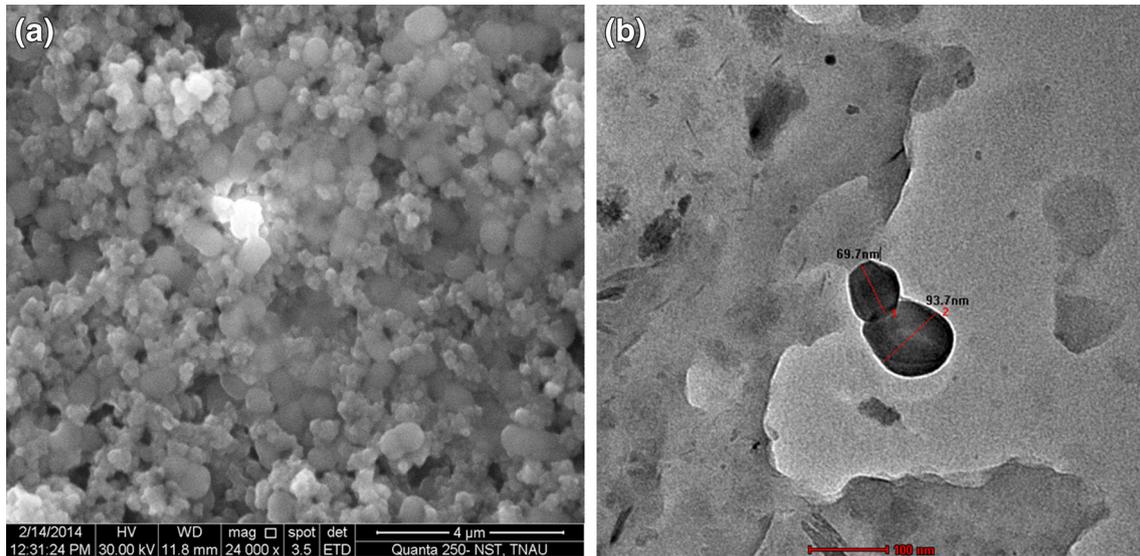
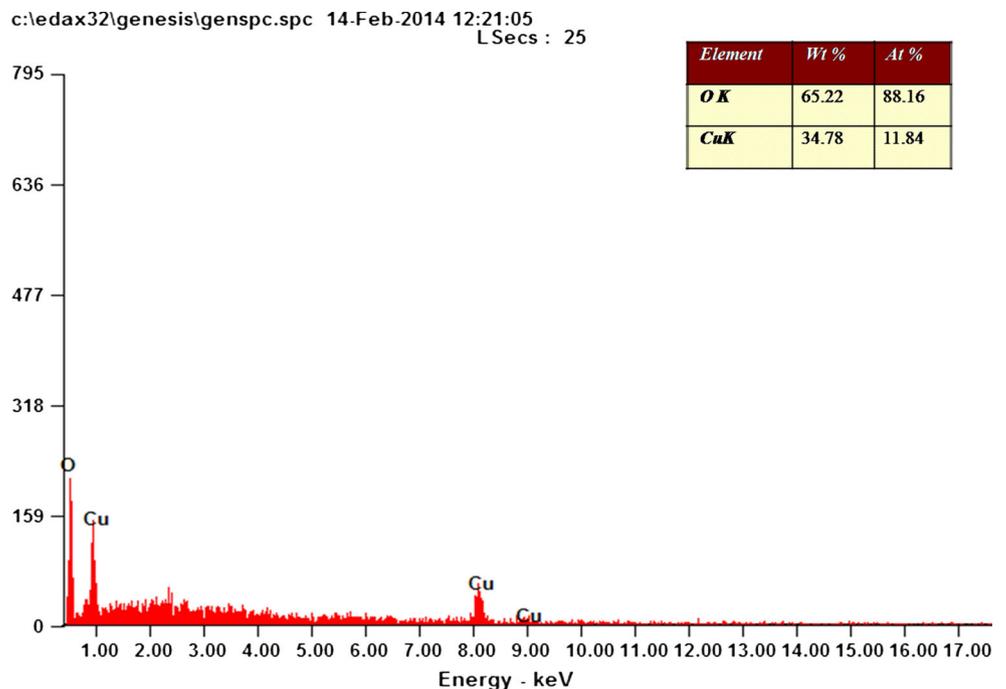


Fig. 2 a SEM. b TEM images of biosynthesized CONPs

Fig. 3 Energy dispersion spectra of synthesized CONPs with sharp elemental signal of copper



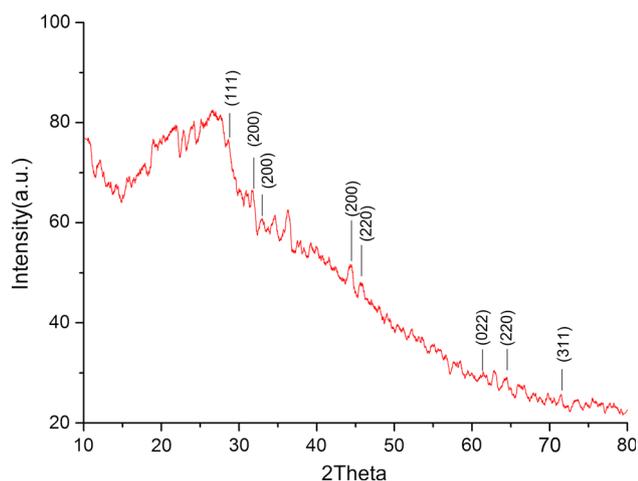


Fig. 4 Powder XRD pattern of CONPs synthesized with *A. lebbbeck* leaf extract

Size and morphology of the CONPs were confirmed by SEM and TEM imaging analysis. The typical SEM image shown in Fig. 2a explained that the morphology of synthesized nanoparticles was observed as roughly spherical. It is evident from that the biosynthesized CONPs were observed as individual particles as well as aggregates. However, nanoparticles are not in direct contact even within the aggregates, indicating stabilization of these particles by phytochemicals present in the *A. lebbbeck* leaf extract. The synthesized CONPs exhibited good uniformity and were mono-dispersive in nature. The monodispersivity of CONPs is a useful parameter for the biomedical applications. The size of the synthesized CONPs was characterized by TEM analysis and size was found to be lesser than 100 nm (Fig. 2b). The elemental composition of the biosynthesized CONPs was confirmed by EDS analysis. The EDS profile showed the presence of strong characteristic copper signal at approximately 1 keV and oxygen signal at approximately 0.2 keV and no other impurity peaks were observed (Fig. 3). EDS results confirmed that highly pure CONPs can be synthesized by using *A. lebbbeck* extract and the additional peaks may be attributed due to some bioorganics present in the solution. Similar results were reported for copper nanoparticles synthesis by sublimated precursors (Soofivand and Salavati-Niasari 2013; Hame et al. 2012). Crystal structure of the nanoparticles was characterized by XRD analysis. The powder diffraction pattern of CONPs is shown in Fig. 4 and different peaks were observed at $(2\theta) = 28.63^\circ$, 32.08° , 44.48° , 46.12° , 61.68° , 64.52° and 71.48° which correspond to the (1 1 1), (2 0 0), (2 0 0), (2 2 0), (0 2 2), (2 2 0) and (3 1 1) lattice planes of cubic CONPs. Results of XRD spectrum indicate the presence and size of copper oxide nanoparticles are in good agreement with UV–Vis spectra and TEM image.

Conclusion

A simple method has been established for the biosynthesis of CONPs employing leaf extract of *A. lebbbeck*. The formation of copper oxide nanoparticles was visually confirmed by the colour change followed by UV–Vis spectral characterization. SEM and TEM studies revealed the shape of synthesized nanoparticles as roughly spherical with a size range of 100 nm. The results of this study showed that *A. lebbbeck* leaf extract can be used as an efficient reducing agent for the facile, eco-friendly synthesis of CONPs in large scale.

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