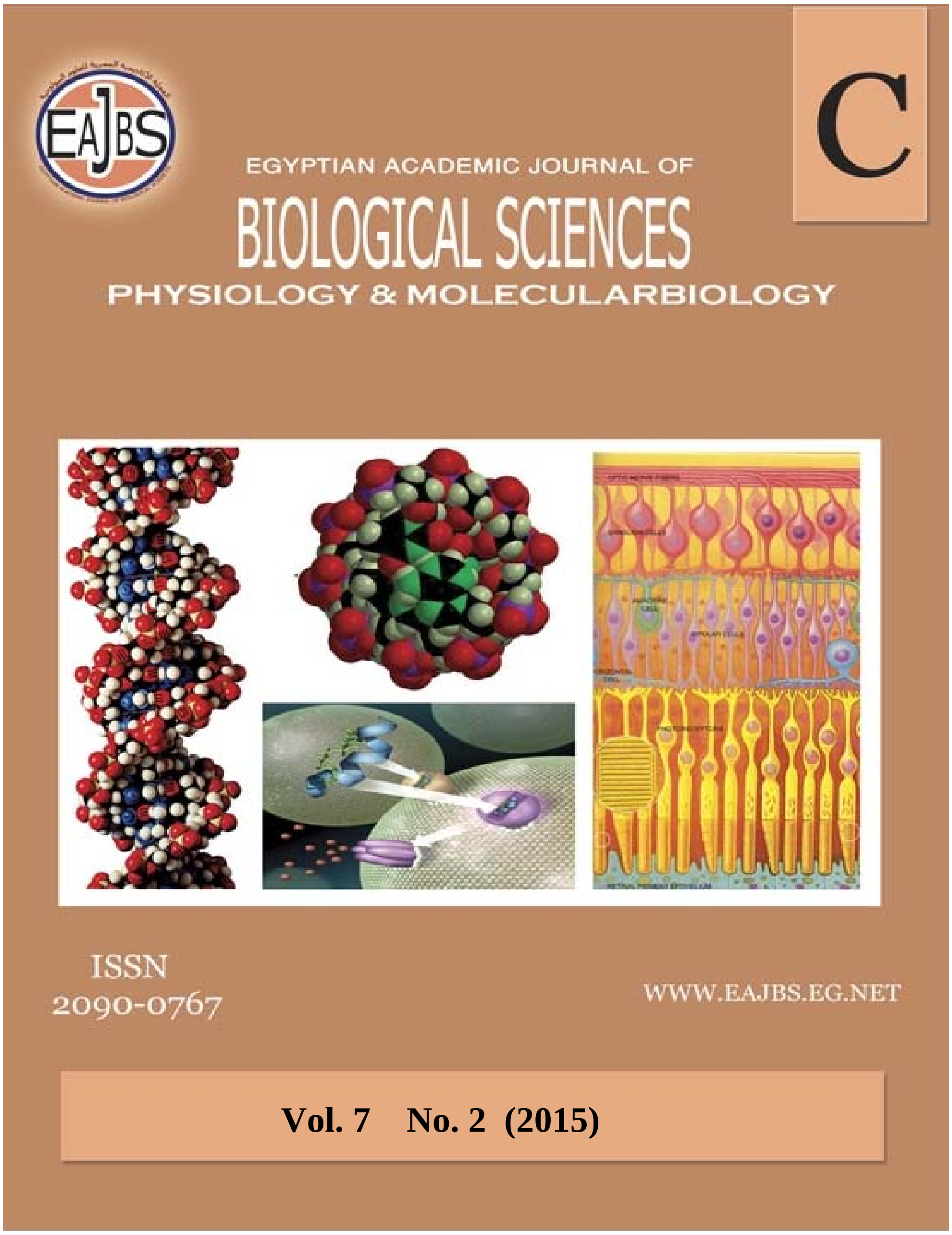

Egyptian Academic Journal of Biological Sciences is the official English language journal of the Egyptian Society for Biological Sciences, Department of Entomology, Faculty of Sciences Ain Shams University.

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Citation :*Egypt. Acad. J. Biolog. Sci. (C. physiology and Molecular biology) Vol.7(2)pp41-46(2015)*

Egypt. Acad. J. Biolog. Sci., 7(2): 41 -46 (2015)

Egyptian Academic Journal of Biological Sciences
C. Physiology & Molecular Biology
ISSN 2090-0767
www.eajbs.eg.net

Phytosynthesis of Gold Nanoparticles Using Leaf Extract of *Sedum pachyphyllum*

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ARTICLE INFO
Article History
Received:7/8/2015
Accepted:17/9/2015

Keywords:
Phytosynthesis
Gold nanoparticle
Leaf extract
Sedum pachyphyllum.

ABSTRACT

The developments of rapid, simple, cost-effective and eco-friendly procedures for the synthesis of nanoparticles are very important in the field of nanotechnology. The present study deals with the green synthesis of gold nanoparticles using leaf extract of *Sedum pachyphyllum* as the reducing agent. The synthesis is carried out at room temperature in the laboratory ambient. Merely, few minutes were necessary for the synthesis of gold nanoparticles. Exposed to leaf extract, the aqueous gold ions were reduced and resulted in gold nanoparticles. The formation of gold nanoparticles was confirmed in the presence of an absorption peak at 556 nm using UV–visible spectrophotometer. Field Emission Scanning Electron Microscopy (FESEM) analysis showed gold nanoparticles, which are about 80 mm. Fourier Transform Infrared Spectroscopy (FTIR) revealed possible involvement of reductive groups on the surfaces of gold nanoparticles. Stable gold nanoparticles were formed by treating an aqueous solution of $HAuCl_4$ with the plant leaf extracts as reducing agent of Au^{3+} to an Au^0. This method provides a safe and green synthesis comparable to more chemical methods and can be used in areas such as medical, foods and cosmetics.

INTRODUCTION

Nanotechnology describes technology and science involving nanoscale particles (nanoparticles) which enhance the range of investigations (Dua and Jiang 2007). Nanoparticles, generally considered particles with a size of up to 100 nm, demonstrate wholly new or enhanced properties as compared to the larger particles of them bulk material (Willems 2005). A newly there has been a large interest in the improvement of techniques for the synthesis of metal-nanoparticles of well-defined size, shape and composition, as they find applications (Morones, Elechiguerra *et al*. 2005, Pal, Tak *et al*. 2007). Ranges of techniques as well as physical and chemical procedures have been developed to synthesize nanoparticles.

The physical procedures (Bae, Nam *et al*. 2002) are expensive (Parikh, Singh *et al*. 2008) and more chemical procedures are potentially dangerous to the environment (Mukherjee, Roy *et al*. 2008). Nanoparticle application in catalysis, sensors, biomedical field, optics and electronics depends critically on their size and composition of the nanoparticles. Thus, diverse methods leading to the synthesis of various nanoparticles have extended the choice of properties that can be obtained. Most of the properties of nanoscale matter are strongly dependent on particles size and shape (Morones, Elechiguerra *et al*. 2005, Mukherjee, Roy *et al*. 2008). Gold nanoparticles have found their use in diagnostic and drug delivery applications and are broadly used in emerging interdisciplinary fields of nanobiotechnology. Their displayed novel properties have more effective and wider biomedical applications (El-Sayed 2004, Kim, Connor *et al*. 2004, Greenfield 2005, Gupta and Gupta 2005, Bhumkar, Joshi *et al*. 2007). Consequently, there is an increasing need to grow environmentally benign nanoparticle synthesis processes without using toxic chemicals in the synthesis protocols (Mukherjee, Ahmad *et al*. 2001). Biological methods for nanoparticle synthesis by means of bacteria (Joerger, Klaus *et al*. 2000), fungi (Mandal, Bolander *et al*. 2006), yeast (Kowshik, Ashtaputre *et al*. 2003) and various parts of the plant such as leaf and flower extracts (Mohanpuria, Rana *et al*. 2008, karimi andeani, Kazemi *et al*. 2011, Karimi Andeani and Mohsenzadeh 2012, Karimi and Mohsenzadeh 2015) have been suggested as possible eco-friendly methods. Biological method used for the synthesis of nanoparticles offers several advantages since it is easier to carry out and more economical than traditional ones (Castro-Longoria, Vilchis-Nestor *et al*. 2011). Previously studies show that different factors including pH, temperature, the kind of organic compounds in the leaf extract and the concentration of $HAuCl_4$ solution and leaf extract can determine the shape of producing nanoparticles. In this paper, we report on the biosynthesis of gold nanoparticles using leaf extract of *S. pachyphyllum* is originally from Mexico (Sierra Mixta, San Luis and Oaxaca). It is an easily grown succulent that can tolerate sun, shade, moist and dry soils and requires little water. This plant previously was not used to synthesize gold nanoparticles in aqueous solutions at ambient conditions, without any additive protecting nanoparticles.

MATERIALS AND METHODS

Biosynthesis of gold nanoparticles

The freshly harvested *S. pachyphyllum* leaves were gained from research greenhouse of the Biology Department, Shiraz University of Iran and used to make the aqueous extract (Fig. 1). Twenty grams of the fresh leaves were thoroughly washed three times in distilled water for 15 minutes, cut into fine pieces and was boiled in an Erlenmeyer flask with 100 mL of sterile water for 5 minutes. Leaf broth was filtrated by filter paper (0.45 μm) and was kept at 4°C for using within a week. In a typical experiment, 12 mL of filtrate solution was added to 12 mL of 1mM $HAuCl_4$ solution at room temperature. After a few minutes, the culture solution was observed to have distinctly deposited precipitate at the bottom of the flask leaving the colloidal supernatant at the top. The precipitated gold nanoparticles obtained were purified by repeated centrifugation at 14,000 RPM for five minutes, followed by re-dispersion of the pellet in deionized water. In this reaction, leaf broth is used for the reduction of Au^{3+} ions to Au^0. The biotransformation of gold ions to nanoparticles was occasionally monitored by means of UV–visible spectrophotometer and with other characterizing techniques.

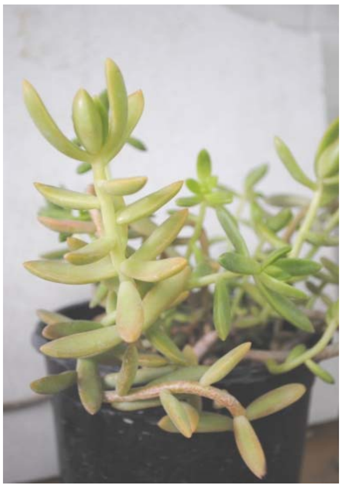

Fig. 1: *Sedum pachyphyllum* plant.

Characterization of gold nanoparticles

UV–visible absorbance spectroscopy

UV-Visible spectroscopy measurements were carried out by computer-controlled UV–visible spectrophotometer Spekol 1500 between 300 and 600 nm as a function of time of the reaction operated at a resolution of 1 nm. An amount of 0.2 ml of the suspension was diluted in 2 ml of deionized water and measured at room temperature and blank for sample was diagnosed water.

Field emission scanning electron microscopy (FESEM) measurement

Using FESEM technique, the size, shape and morphology of the Au nanoparticles were examined. Dried suspension of gold nanoparticles is synthesized by a reduction between gold ions, and leaf extract of *S. pachyphyllum* was used for analysis. The field emission scanning electron microscope (Hitachi S-41 FESEM, model XL30) was applied at an accelerating voltage of 15 kV.

Fourier transforms infrared (FTIR) spectroscopy measurements

After entire reduction of gold ions by the *S. pachyphyllum* leaf extract, the solution was centrifuged at 14,000 RPM for 10 minutes to isolate Au nanoparticle free from proteins/enzymes or other Bioorganic compounds present in solution. The Au nanoparticles pellet was obtained after centrifugation and were redispersed in water and washed with distilled water for three times. For FTIR measurements, the samples were dried and ground with KBr pellets and analyzed in an SHIMADZU FTIR-8300 model in the diffuse reflectance mode operating at a resolution of 4 cm^{-1}.

RESULTS

The reduction gold ions using leaf extract led to the formation of nanoparticles at room temperature. During this reaction, the color of leaf extract was changed. This change of color was recorded by UV-visible spectrophotometer. The absorption spectrum of synthesized gold nanoparticles after few minutes shows an absorbance peak at near 556 nm (Fig. 2). It is well known that the appearance of purple colors in the reaction mixture indicates the formation of Au nanoparticles. The absorption peaks located between 520 and 580 nm were observed for the synthesized Au nanoparticles (Mulvaney 1996). The formation of gold nanoparticles as well as their morphological dimensions of the FESEM study demonstrated that the average size of spherical shape particles was 80 nm (Fig. 3).

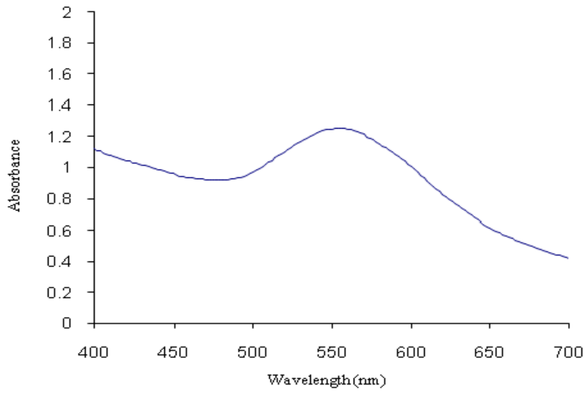

Fig. 2: UV-visible absorption spectrum recorded of synthesized gold nanoparticles.

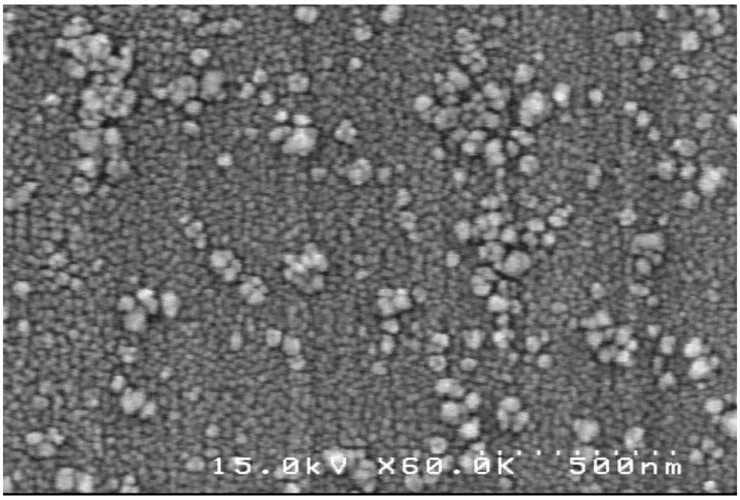

Fig. 3: FESEM images of gold nanoparticles synthesized from the leaf extract of *Sedum pachyphyllum*.

The images show the density of gold nanoparticles synthesized by the *S. pachyphyllum* leaf extract and confirm the development of gold nanostructures by the plant extract. Fourier transformed infrared spectroscopy was used to identify the possible biomolecules responsible for the reduction of the gold ions and capping of the produced gold nanoparticles synthesized by the leaf extract. (Fig. 4), shows that FTIR peaks at 1211, 1388, 1643, 2360, 2893 and 3440 cm^{-1} represents the different functional groups of the adsorbed biomolecules on the surface of the gold nanoparticles.

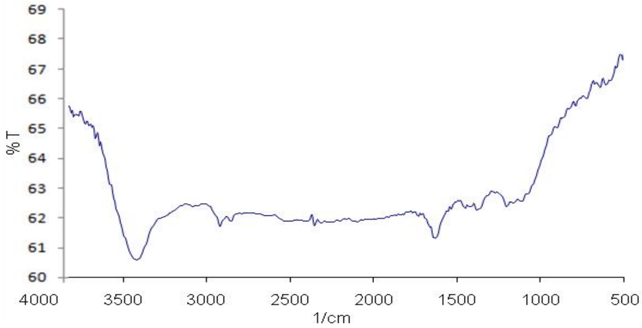

Fig. 4: FTIR spectrum recorded by making KBr disc with synthesized gold nanoparticles synthesized.

DISCUSSION

The improvement of eco-friendly synthetic methods for the creation of nanostructure materials at a lower cost and energy may lead to a wider range of applications in the field of nanotechnology. The biological synthesis of gold nanoparticles using leaf extract of *S. pachyphyllum* has demonstrated that it is simple, rapid and green method for producing gold nanoparticles at room temperature and extracellular without adding different physical and chemical steps. According to the spectrum recorded by making a KBr disc with synthesized gold nanoparticles synthesized (figure 4), the absorption peak at around 1211 confirmed the amide III of proteins, peak at 1385 cm^{-1} corresponding to the germinal methyl group. The peak at 1643 cm^{-1} can be assigned to the amide I band of the proteins and aromatic rings. Accordingly, 2893 and 2931 indicated the secondary amines and C–H stretches, vibration modes in the hydrocarbon chains (CH aliphatic). The characteristic of the hydroxyl functional group in alcohols and phenolic compounds was 3360 cm^{-1}, finally 3440 cm^{-1} was related to N–H stretching. This result suggested the presence of proteins on the surface of Au core particles. The previous reports suggested that proteins can bind to Au nanoparticles through free amine groups in the proteins (Gole, Dash *et al*. 2001). The variations in the peak positions indicated that the proteins and metabolites such as terpenoids having functional groups of amines, alcohols, ketones, aldehydes, and carboxylic acids responsible for synthesis of Au nanoparticles. In this study, we have reported the successful synthesis of gold nanoparticles using reduced gold ions present in aqueous solution of $HAuCl_4$ complex by the extract of *S. pachyphyllum* leaves. We were able to get the gold spherical nanoparticles. In addition, the use of *S. pachyphyllum* leave extract for the production of other metallic nanoparticles with controlled characteristics using ecological methods will be achieved in a short period of time.

ACKNOWLEDGMENTS

The authors would like to thank the Shiraz University Research Council for supporting this research.

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