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Green synthesis and characterization of iron oxide nanoparticles by pheonix dactylifera leaf extract and evaluation of their antioxidant activity

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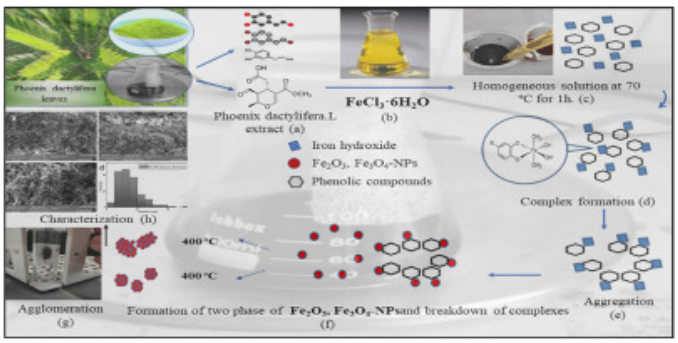
Abstract

The development of green nanotechnology is generating research interest in the ecological biosynthesis of nanoparticles (NPs). In this study, the biosynthesis of stable iron nanoparticles was carried out using *Phoenix dactylifera L.* extract which is able to reduce iron ions to iron nanoparticles. The process comprises maceration extraction overnight and heat treatment of the extract with iron chloride ($FeCl_3$) at 70 °C for 1 h. X-ray diffraction (XRD), scanning electron microscope (SEM), and Fourier transform infrared spectroscopy (FTIR) were used for nanoparticle characterization. The stability of the bioreduced iron nanoparticle was analyzed using UV-VIS absorption spectra, and their antioxidant and anti-radical activities were measured against PhosPhoMolybdate (PPM) and 2,2-diphenyl-1-picryl-hydrazyl (DPPH), respectively. The results demonstrate that ecological biosynthesis of 2–30 nm stable iron nanoparticles of size with antioxidant activity can be achieved suggesting their possible applications.

Graphical abstract



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Introduction

Nanoscience is the study of materials with one or more dimensions in the range of 1–100nm. These materials are produced by atom/molecule organization or by the destruction of a macroscopic material. Nowadays, the manufacturing technology of nanomaterials is growing interest in view of their widespread use for a variety of applications in many industrial sectors (Darroudi et al., 2014/11; Chaudhuri and Malodia, 2017/11) Among nanomaterials, nanoparticles (NPs) are especially interesting due to their capacity to act as a bridge between macroscopic materials and atomic structures. Macroscopic materials exhibit constant properties, regardless of their size and mass. However, the properties of NPs depend on their size due to the great relative proportion of superficial atoms with respect to their volume. Nanoparticles, because of their specific and unique properties, are currently being used in many high-tech fields, such as the medical sector for diagnostics, antimicrobial purposes and drug delivery systems (Parveen et al., 2012/02; Gholami et al., 2018/06), the electronics and optoelectronics industry (Phillips et al., 2011), the chemical sector for catalysis (Shiju and Guliants, 2009/03), for the protection of the environment (Ju-Nam and Lead, 2008/08) and the conversion of energy (Kim et al., 2010/10). In fact, Iron oxide nanoparticles (Fe-NPs) are particularly interesting in modern nanotechnology research because of their unique properties, which make them fit a wide range of applications (Teja and Koh, 2009/03; Laurent et al., 2008).

The synthesis of nanoparticles is usually carried out by various chemical methods such as pyrolysis, sol-gel transition, supercritical fluid synthesis and chemical deposit in steam phase or by a variety of physical methods such as engraving, mechanical milling, ablation laser, thermal decomposition and lithography (Muthuchamy et al., 2020; Justin et al., 2017). Most of these methods are expensive and/or require the use of toxic solvents (Ahila et al., 2018; Sun et al., 2011). On the other hand, great efforts have recently been made to use environmentally friendly methods for the synthesis of noble metal nanoparticles (Toropov and Vartanyan, 2019). Such effort has produced the so-called green methods, aiming for providing highly pure nanoparticles through simple, economic and repetitive techniques.

This is mainly achieved through the use of plant or fruit extracts (Ghodake et al., 2010) and bio-organisms (Sanghi and Verma, 2009) along with polyphenols, which catalyze the synthesis of nanoparticles thanks to their unique properties (nucleophilia, reducing character, polarizability, ability to form hydrogen bond, acidity and ability to chelate metal ions) (Zayed and Eisa, 2014). These green methods are inexpensive, fast, effective and generally lead to the formation of crystalline nanoparticles with a variety of shapes (spheres, stems, prisms, plates, needles, leaves or dendrites) and sizes. These characteristics depend mainly on the parameters used in the process, such as the nature of the plant extract, the relative concentrations of the extract and the metal salts, the pH, the temperature and the reaction time, as well as the mixing rate of vegetable extract and metallic salts (Noruzi et al., 2011).

Phoenix dactylifera L. is one of the plants with higher polyphenol content. They are considered bioactive molecules and act both as a reducing and capping agent. For this reason, it has gained immense popularity in various fields from therapeutics to food additives. Although its use as an antioxidant additive is restricted, these properties could lead to the synthesis of nanoparticles with different and unique properties (Bayraktar et al., 2017; Gajanan et al., 2011).

The overall objective of this work was to study the synthesis of Fe-NPs using *Phoenix dactylifera L.* extract and to characterize these nanoparticles using XRD, SEM, UV visible and FTIR to demonstrate that the iron oxide nanoparticles synthesized by this procedure contain certain compounds with antioxidant activity and that, therefore, they could be used as natural antioxidant additives in pharmaceutical and food products.

Section snippets

Materials

Iron(III) chloride hexahydrate 98% ($FeCl_3{\cdot}6H_2O$), methanol (CH_3OH), sulfuric acid (H_2SO_4), sodium phosphate (Na_2HPO_4), ammonium molybdate ($(NH_4)_3PMo_{12}O_{40}$), 2,2-diphenyl-1-picrylhydrazyl (DPPH), gallic acid ($C_7H_6O_5$), hydrochloric acid (HCl) and dimethyl sulfoxide anhydrous (DMSO) 99.9% (C_2H_6SO) were purchased from Sigma Aldrich. All other chemicals and reagents used in this study were of analytical grade.

The *Phoenix dactylifera L.* plants were collected from Texebt EL-Oued province, Algeria.…

Phoenix leaf extract and nanoparticle manufacture

The…

Characterization of nanoparticles by X-ray diffraction (XRD)

The aim in this section was to verify whether a larger nanoparticle size, made the composition of the spinel phase to be closer to that of magnetite, in accordance with the results reported in the literature (Noruzi et al., 2011; Bayraktar et al., 2017; Gajanan et al., 2011). The X-ray diffractograms of the powders synthesized by the Phoenix extract at 70°C and heat-treated at 400°C are shown in Fig. 1.

The intensity of the diffraction peaks indicates good crystallinity of the nanoparticles.…

Concluding remarks

It is well-known that the chemical and physical synthesis of nanoparticles cannot be easily developed at a large-scale production due to of several disadvantages, such as the presence of toxic organic solvents, the production of hazardous by-products and intermediate compounds and high energy consumption. As a result, alternative biological methods that could be more environmentally friendly and cause no harm to human and domestic animals health are being developed.

In this work, a green a green …

CRediT authorship contribution statement

J. Amin Ahmed Abdullah: Writing - original draft, Formal analysis. **Laouini Salah Eddine:** Writing - original draft, Formal analysis. **Bouafia Abderrhmane:** Writing - original draft, Formal analysis. **M. Alonso-González:** Writing - original draft, Formal analysis. **A. Guerrero:** Writing - original draft, Formal analysis. **A. Romero:** Writing - original draft, Formal analysis.…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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