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Phytosynthesis of Silver Nanoparticles Using *Leonurus cardiaca* L. Extracts

Ioana Catalina Fierascu [1,†], Irina Fierascu [2,3,†], Anda Maria Baroi [2,3], Camelia Ungureanu [4,†], Simona Spinu [3], Sorin Marius Avramescu [5], Raluca Somoghi [2], Radu Claudiu Fierascu [2,4,*,†] and Cristina Elena Dinu-Parvu [1]

1 Faculty of Pharmacy, University of Medicine and Pharmacy "Carol Davila", 37 Dionisie Lupu Str., 030167 Bucharest, Romania; ioana.fierascu@drd.umfcd.ro (I.C.F.); cristina.dinu@umfcd.ro (C.E.D.-P.)
2 National Institute for Research & Development in Chemistry and Petrochemistry—ICECHIM Bucharest, 202 Spl. Independentei, 060021 Bucharest, Romania; irina.fierascu@icechim.ro (I.F.); anda.baroi@icechim.ro (A.M.B.); raluca.somoghi@icechim.ro (R.S.)
3 Faculty of Horticulture, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 011464 Bucharest, Romania; simonaspinu91@gmail.com
4 Faculty of Chemical Engineering and Biotechnologies, University "Politehnica" of Bucharest, 313 Splaiul Independentei Str., 060042 Bucharest, Romania; ungureanucamelia@gmail.com
5 Faculty of Chemistry, University of Bucharest, 91–95 Splaiul Independentei, 050095 Bucharest, Romania; sorin_avramescu@yahoo.com
* Correspondence: fierascu.radu@icechim.ro
† These authors contributed equally to this work.

Abstract: The present work describes, for the first time in the literature, the phytosynthesis of silver nanoparticles using *Leonurus cardiaca* L. extracts. The influence of the extraction method (classical temperature extraction and microwave extraction), as well as of the extract concentration on the characteristics of the nanoparticles, was studied using analytical methods, such as UV-Vis spectrometry, X-ray diffraction, dynamic light scattering, and transmission electron microscopy. Experimental data suggest that use of lower extract concentration leads to smaller dimensions nanoparticles, the same effect using the extract obtained by microwave-assisted extraction. The smallest recorded crystallite sizes (by X-ray diffraction) were under 3 nm. The antioxidant properties (determined by the DPPH assay) and the antimicrobial potential (determined against Gram-negative and Gram-positive strains) are enhanced by the phytosynthesis process (as demonstrated by the comparison of the nanoparticles' properties with the parent extracts). The present work could also represent an important step in obtaining nanoparticles with enhanced properties and controlled morphologies, but also offers information on the phytosynthesis of metallic nanoparticles using low extract concentrations.

Keywords: phytosynthesis; *Leonurus cardiaca* L.; silver nanoparticles; antioxidant; antimicrobial

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1. Introduction

The amazing world of plants offers new possibilities to obtain specific materials with a vast range of potential applications. Nowadays, plant-derived materials are used in various areas, from novel therapeutic instruments for disease treatment to environmental applications or development of sensory materials [1–3]. Due to their rich chemical composition, plants are considered to be potential candidates for the development of a new generation of nanomaterials, using "eco-friendly" methods, with a much lower environmental impact, involving the use of non-hazardous reagents and chemicals, as well as having lower production cost and energy consumption [4,5]. Even if we are speaking of medicinal and aromatic plants, non-edible plants or agro-wastes, there is great interest in the phytosynthesis of metal nanoparticles using such plants extracts; the main challenge in the phytosynthesis process is represented by the development of nanoparticles (NPs) with controlled compositions, sizes, shapes, and polydispersity, using different types of

Unlike the previously presented results [39], no significant differences can be found between the NPs solution in terms of antimicrobial potential, the samples demonstrating good antimicrobial potential at all tested concentrations.

4. Conclusions

The present work reports, for the first time in the literature, the phytosynthesis of silver nanoparticles using *Leonurus cardiaca* L. aerial parts extracts. The work also presents the influence of the extraction methods (classical temperature extraction and microwave-assisted extraction) and of the extract concentration on the morphological and biological properties of the NPs (established by determining the antioxidant potential and the antimicrobial properties against *Enterococcus faecalis* and *Escherichia coli*).

The results obtained support the phytosynthesis of silver nanoparticles using *L. cardiaca* extracts, the lowest nanoparticles dimensions being obtained using the extract developed using a microwave-assisted method at a concentration of 1 mg/mL (dimensions being confirmed by UV-Vis determinations, determination of crystallite size by XRD and by DLS measurements).

The AgNPs solutions possesses an enhanced antioxidant potential compared with the parent extracts, determined by the DPPH assay; all tested experimental variants had significant antimicrobial properties (against both Gram-negative and Gram-positive lines). At the same time, the differences between the dimensions of the nanoparticles did not strongly influence the final antimicrobial properties (as the differences recorded are not statistically significant). The antioxidant potential of the NPs was statistically influenced by the extract concentration used, being also influenced, in a smaller extent, by the NPs sizes.

The study demonstrates that the motherwort extracts are able to phytosynthesize silver nanoparticles with significant biological activities, thus allowing the proposal of nanotechnological approaches for future biomedical applications.

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