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STUDY OF EFFECT OF SILVER NANOPARTICLES SYNTHESIZED USING EXTRACT FROM SIDERITIS SCARDICA, INCORPORATED INTO WATER-BASED AND UV COATINGS

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Introduction

In this work, we present an efficient and rapid green method for silver nanoparticles synthesis by using extract from Sideritis Scardica and direct sunlight irradiation. The synthesized nanoparticles were characterized by UV-Vis spectroscopy and Transmission Electron Microscopy (TEM). Then, the as obtained silver nanoparticles were mixed with water-based varnish, which is widely used for paperboard packaging in the food industry, pharmaceutical industry and others.

Evaluation of the results of a microbiological study showed that water-based varnish with incorporated silver nanoparticles exhibited antibacterial activity against Escherichia coli K12 NBIMCC 407 bacteria and Bacillus subtilis NBIMCC 3562 bacteria.

From the results obtained it is clear that these water-based and UV coatings with incorporated silver nanoparticles could find industrial applications in medicine and food industry as packaging with antibacterial properties.

Problem Description

Silver nanoparticles are increasingly used across various fields due to their unique physical and chemical properties. The biological, also known as 'green,' synthesis of nanoparticles is attracting great attention as a reliable, sustainable, and environmentally friendly approach for synthesizing a wide range of nanomaterials, including metal and metal oxide nanomaterials, hybrid, and biomaterials. In this method, biomolecules replace traditional stabilizers and reducing agents.

The main goals of the present study are to synthesize silver nanoparticles by the “green” method, to implement them in different types of packaging coatings and to investigate their antimicrobial activity.

Methods

Silver Nanoparticles Synthesis
According to the green method, silver nanoparticles were synthesized by Sideritis scardica.
The synthetized silver nanoparticles were analyzed by UV-Vis spectrophotometer (T60, PG Instruments Ltd., U.K.). The samples morphology was observed by Transition Electron Microscopy (TEM) on a JEOL JEM 2100, 80-200 kV (Jeol Ltd. Japan).

Mixing Silver Nanoparticles with two types of coatings.
In this study, two types of coatings were utilized: water-based and UV-curable. Silver nanoparticles, synthesized using a 7 mmol/L $AgNO_3$ solution, were incorporated into each varnish at two volume percentages: 20% and 30%. The total volume of each mixture was 50 mL. After adding the nanoparticles, the dispersions were thoroughly homogenized by stirring.

Antibacterial experiments
The antibacterial activity of the two types of Varnish was evaluated against facultative anaerobic Gram-negative E. coli K12 and aerobic Gram-positive B. subtilis 3562 by using the agar disk diffusion test.

Results

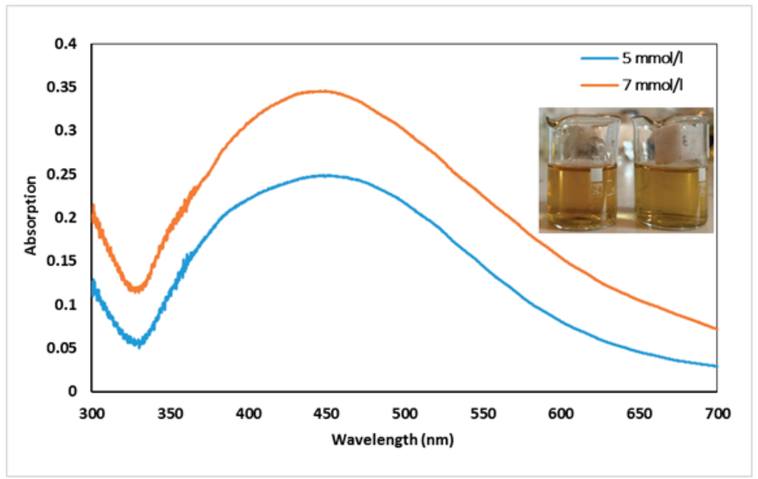

Figure 1

UV-Vis spectra of silver nanoparticles synthesized with 5 mmol/l and 7 mmol/l aqueous solution of silver nitrate and extract from Sideritis scardica for 10 minutes under direct sunlight.

In Figure 2. TEM images at different magnifications revealed spherical particles ranging from 10 nm to 100 nm. The electron diffraction patterns showed concentric rings, confirming the crystalline structure of the nanoparticles.

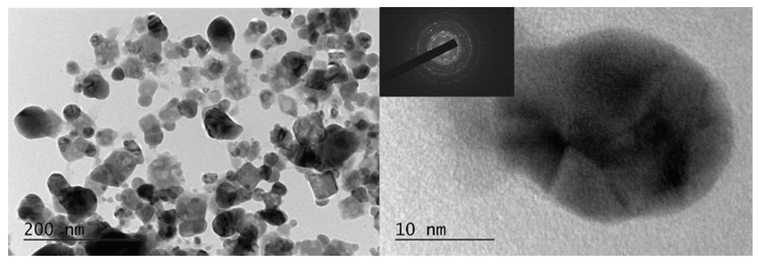

Figure 2

TEM images and the corresponding electron diffraction patterns of silver nanoparticles obtained with Sideritis scardica extract.

Bacterial strain	Coating 1 (water based)		Coating 2 (UV)	
	20 vol%	30 vol%	20 vol%	30 vol%
	Inhibition zone (mm)			
B. subtilis 3562	18.3	18.0	14.5	0
E. coli K12	0	9.5	8.5	9.33

Table 1

Antibacterial test results of Varnish 1 and 2 samples against B. subtilis 3562 and E. coli K12

In Table 1 are presented the results from the agar disk diffusion test. Coating 1 (water-based varnish) and Coating 2 (UV varnish) were tested at two volume concentrations of the antibacterial agent: 20 vol% and 30 vol%. The inhibition zones are measured in mm.

Both samples showed antibacterial activity which was more pronounced against the Gram- positive strain. AgNPs have exhibited significant antibacterial effect against multiple bacteria.

A maximum inhibition zone of 18.3 mm was observed for the Varnish 1 sample (20%). According to our results, the last mentioned is a stronger antibacterial agent than Varnish 2. No inhibition was observed against the E. coli K12 strain when a smaller amount of the antibacterial agent was added.

Discussion / Conclusion

Experiments were conducted to explore the "green" synthesis of silver nanoparticles using Sideritis scardica extracts, utilizing direct sunlight and continuous stirring with a magnetic stirrer. This approach is energy-efficient, stable, and straightforward, requiring no advanced technology, and results in the formation of well-defined nanoparticles. Sunlight facilitates a cost-effective and rapid synthesis process, minimizing the risk of particle agglomeration. UV-Vis spectra revealed distinct peaks characteristic of well-formed nanoparticles. Transmission electron microscopy (TEM) analysis confirmed the presence of spherical silver nanoparticles with sizes ranging from 10 nm to 100 nm.

The integration of silver nanoparticles into two types of coatings (water based and UV) was investigated to assess whether the resultant products exhibit antibacterial activity. Microbiological tests were conducted using two bacterial strains. The results demonstrated that both types of varnish exhibited antibacterial activity, with a more pronounced effect against the gram-positive strain. The water-based varnish sample showed a maximum inhibition zone of 18.3 mm.

The results obtained from the conducted experiment shows that the addition of silver nanoparticles obtained by the “green” synthesis to different types of coatings increases their antibacterial activity. Improving the antibacterial properties of coatings is important from a scientific and applied point of view, due to the great possibilities for practical application in the field of packaging of foods, medicines, etc. Refinement of the concentrations of silver nanoparticles, expansion of the types of researched coatings in the field of packaging is pending. A number of experiments will be conducted with applying of variety of quantities and different anilox rollers, on papers and cardboards in order to study their antibacterial properties and practical application of this method.

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