A step towards Green Nanotechnology: biomass-NADES extracts for the development of nanocomposite alginate-silver nanoparticles hydrogels

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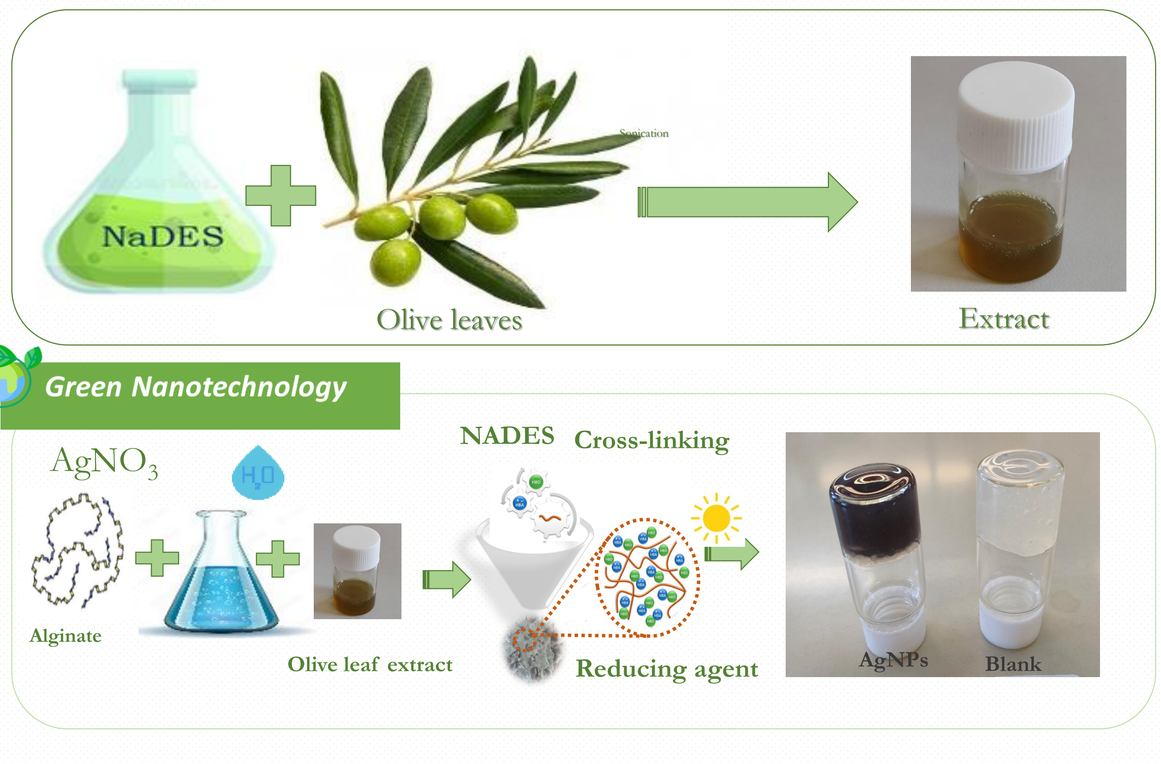
Introduction

Silver nanoparticles (AgNPs) have gained significant attention in the field of biomedicine due to their remarkable antibacterial and antimicrobial properties. In the present work, a method to prepare alginate hydrogel impregnated with AgNPs is developed. A **Natural Deep Eutectic Solvent (NADES)** was used as extraction solvent in order to obtain an extract with high antioxidant (thus reducing) activity from chamomile and olive leaves. The **NADES-extract** was used 'as-obtained': **(a)** as **reducing agent** for the formation of AgNPs inside the polymer network in the presence of sunlight and **(b)** as **crosslinker** for the formation of hydrogels.

Materials & Methods

Green in situ synthesis of AgNPs within alginate hydrogel

- ✓ **Natural Deep Eutectic Solvents (NADES)** were used as **extraction solvents**, in order to obtain an extract of high antioxidant activity
- ✓ The **NADES-extract** was used "as obtained" as **reducing agent** and simultaneously as **crosslinker** for the formation of hydrogels



Olive leaf Extraction

- NADES as extraction solvent
- Ultrasonic-assisted extraction (UAE)

In situ synthesis of AgNPs in hydrogel

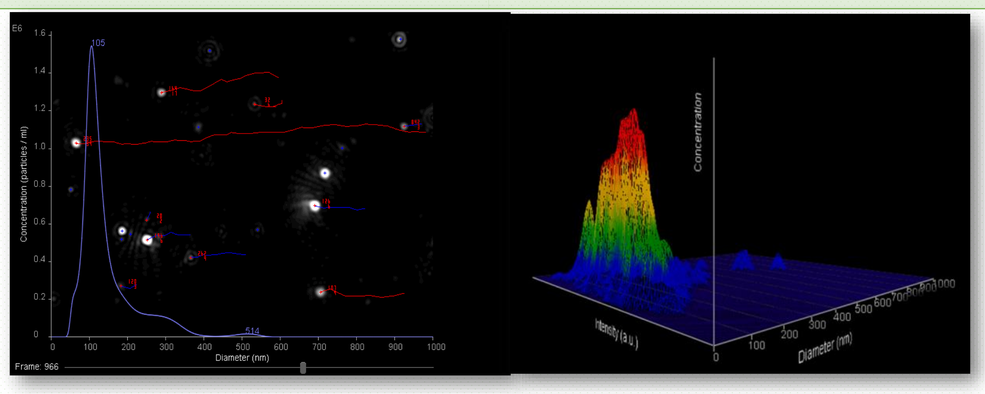
- Green *in situ* synthesis of silver nanoparticles in alginate hydrogels using olive leaf extract as the reducing agent and crosslinker

Results & Discussion

Characterization of AgNPs

- ✓ The AgNPs were characterized using **Nanoparticle tracking analysis (NTA), Dynamic light scattering (DLS)** and **UV-Vis spectroscopy**

Sample	Size (nm)	ζ-potential (mV)	Concentration (10^8particles/ml)
AgNPs Hydrogels	**103.2±5.6**	**-36.9±0.9**	**1.21**



- ✓ The **zeta potential** and **PDI** values of AgNPs indicate increased **stability** of the AgNPs in the hydrogel matrix

Antimicrobial activity of the hydrogels

- ✓ The growth curves of the microorganisms as produced by Bioscreen C, indicated that hydrogels exert bacteriostatic activity against the tested bacteria both gram negative and gram positive (figure 1)
- ✓ The highest bacteriostatic activity was observed in all cases with hydrogels with NADES-olive leaf extract and AgNPs but also hydrogels with NADES and olive leaf extract exhibited antimicrobial activity

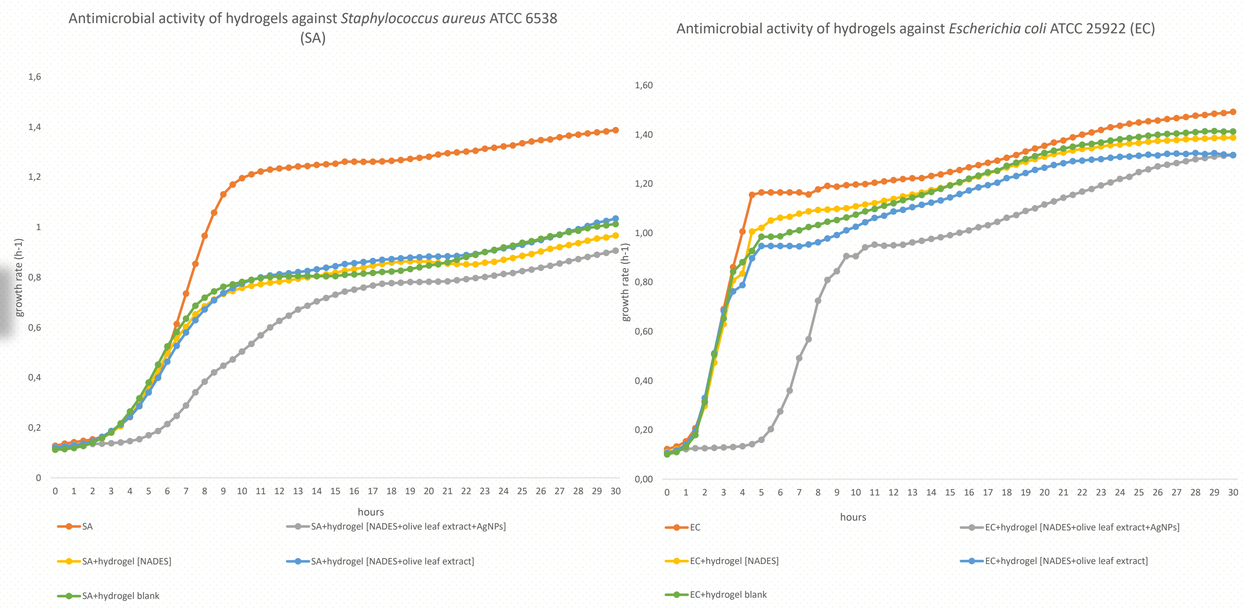


Figure 1: Growth curves of a) *Staphylococcus aureus* ATCC 6538 and b) *Escherichia coli* ATCC 25922, in absence of hydrogels (SA or EC) and in the presence of hydrogels (SA or EC+hydrogel). An extended lag phase and a slower growth rate is observed in case there is antimicrobial activity. The hydrogel with NADES+olive leaf extract+AgNPs was shown to have the highest antimicrobial activity.

Conclusions

- ✓ **Olive leaf biowaste** was extracted using a **NADES** consisting of **glucose/lactic acid/water**
- ✓ The **extract** efficiently acted as the **reducing agent** for the formation of silver nanoparticles in alginate hydrogels in the presence of **visible light**
- ✓ Main advantage of this approach is that the **NADES** acts as a **crosslinking agent** requiring no additional chemicals
- ✓ The photo-induced phytomediated ***in situ* synthesis of AgNPs** within a hydrogel is a **highly promising, economical and environmentally friendly** method for the preparation of multifunctional materials.

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