Green Synthesis of Silver Nanoparticles Using Pomegranate Peel Extract: An Optimized Approach for Antibacterial Applications

Dr. Rocío Díaz-Puertas

Nanomaterials 2026: Innovations and Future Perspectives

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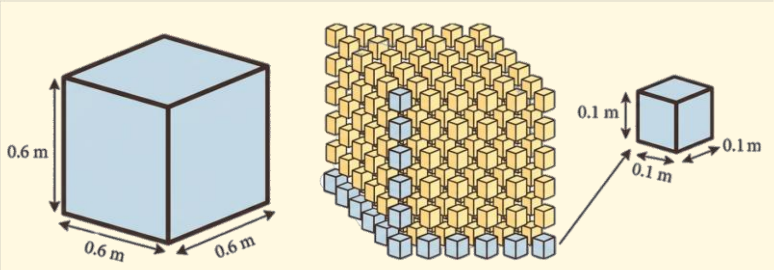
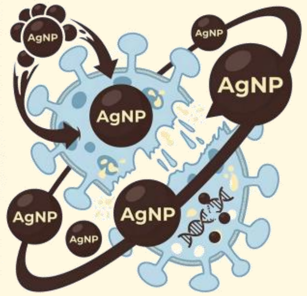
Nano-materials 2026 Conference

Silver nanoparticles

Unique characteristics



AgNPs



Strong antibacterial activity

Valuable in diverse applications

Textiles

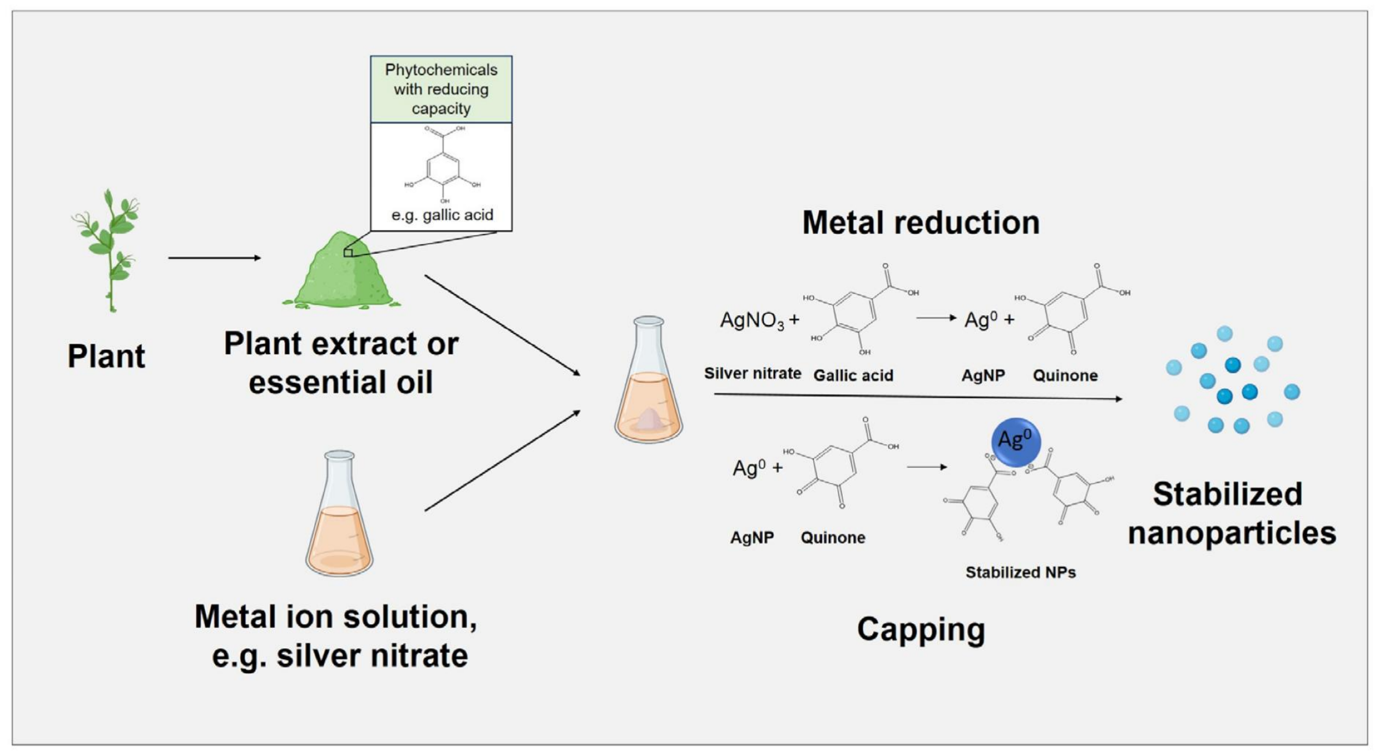
Energy

Dressings

Green synthesis

Advantages:
- environmentally friendly
- cost-effective
- uses natural reducing agents
- sustainable

Plant extracts contain **polyphenols, tannins and flavonoids** that can reduce Ag^{+} ions and stabilize nanoparticles.



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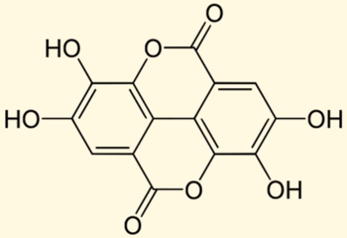
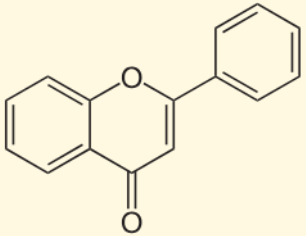
Pomegranate peel

Agricultural waste product

Valorization of agro-waste

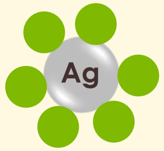


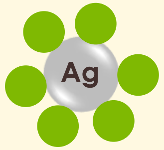
Rich in bioactive compounds



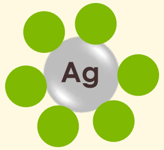
Punica granatum

Widely cultivated in the Mediterranean region





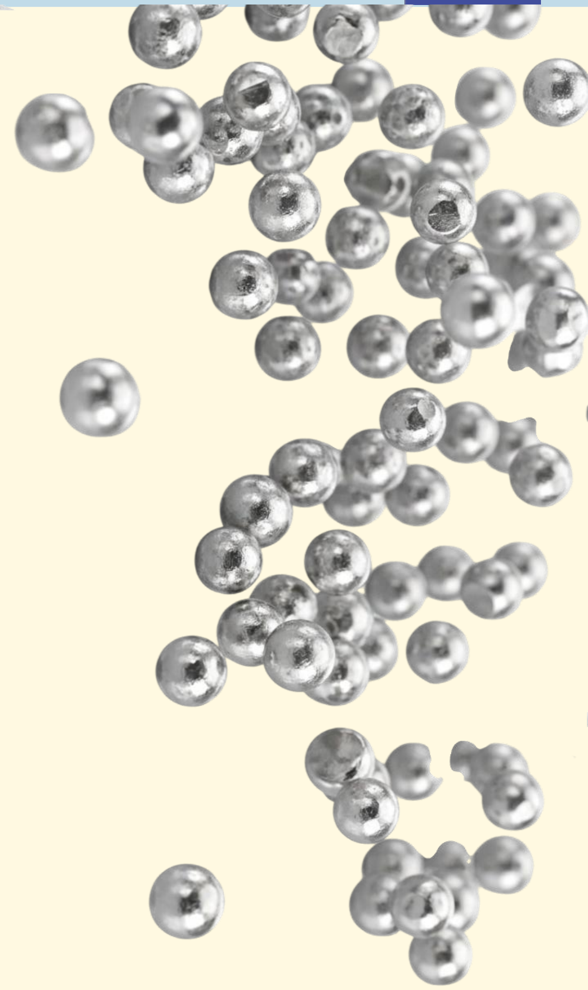
Reducing and capping agents



Objectives

The **objective** of this work was to **develop an optimized green synthesis method for silver nanoparticles using pomegranate peel extract.**

1. Synthesize AgNPs using peel extract as reducing agent.
2. Optimize synthesis parameters using Box-Behnken design.
3. Characterize nanoparticles.
4. Evaluate antibacterial activity.
5. Integrate into nanofibers.



Green synthesis methodology

Phytochemical

Extract of *Punica granatum*

➕

Metal salt

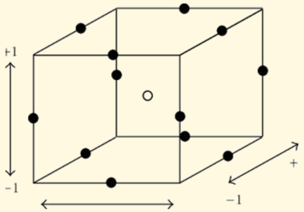
$AgNO_3$

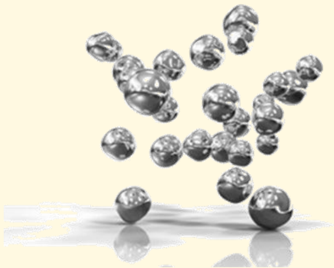
Synthesis optimization

Temperature

$AgNO_3$ concentration

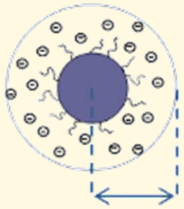
PGE concentration

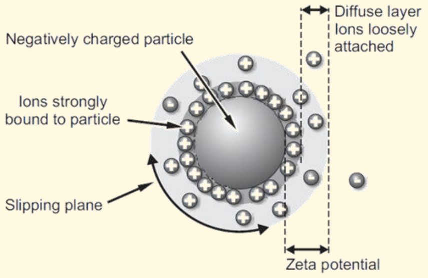




Optimized AgNPs

AgNP-HDD	AgNP-PDI	AgNP-ZP	AgNP-OPT
↓ HDD	↓ PDI	↓ ZP	↓ HDD ↓ PDI ↓ ZP





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Green synthesis methodology

Phytochemical

Extract of *Punica granatum*

+

Metal salt

$AgNO_3$

Synthesis optimization

Temperature

$AgNO_3$ concentration

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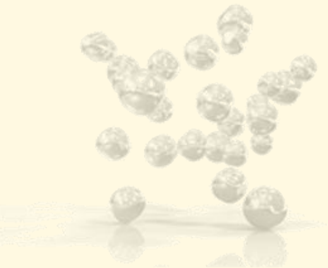


Optimized AgNPs

AgNP-HDD

↓ HDD

AgNP-PDI

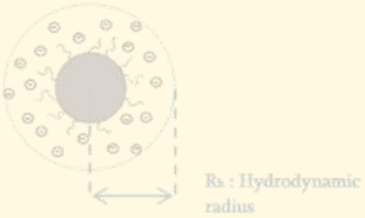
↓ PDI

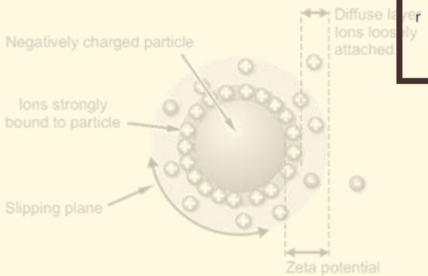
AgNP-ZP

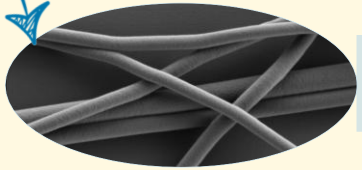
↓ ZP

AgNP-OPT

↓ HDD
↓ PDI
↓ ZP





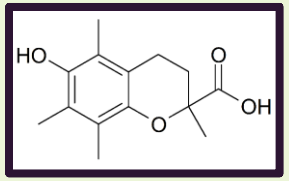


0.2% w/w in 15% BSA/3% PEO solution

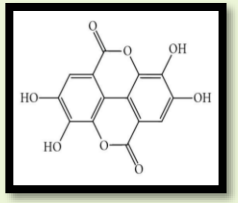
Characterization

EXTRACT

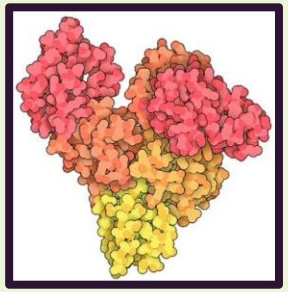
HPLC (high performance liquid chromatography)



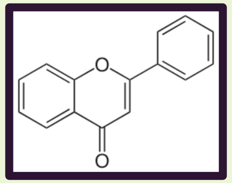
Antioxidant capacity



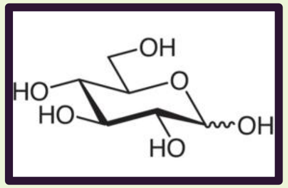
Total phenolic content



Protein determination



Flavonoid content



Total reducing sugars

AgNPs

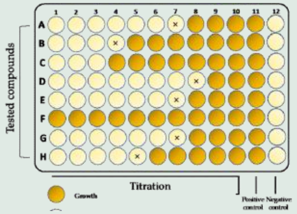
Field emission scanning electron microscopy (FESEM)

X-ray diffraction (XRD)

Fourier transformed infrared spectroscopy (FTIR)

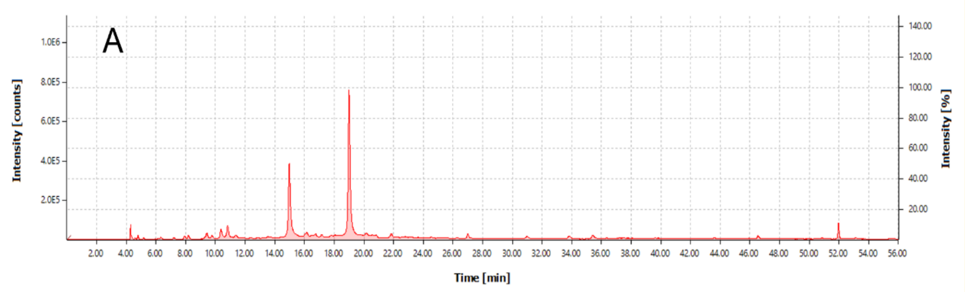
Uv-vis spectroscopy

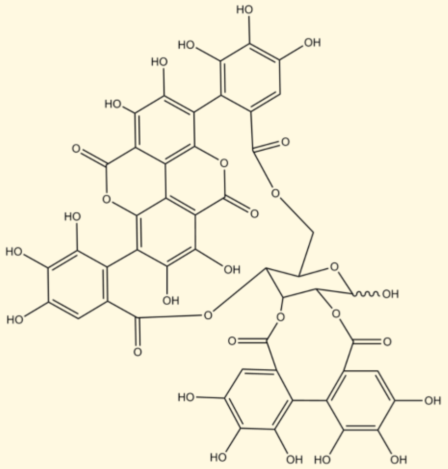
Dynamic light scattering (DLS)



Antimicrobial microdilution assays - *E. coli* and *S. aureus*

Extract composition





Punicalagin

Total polyphenolic content	29.94 ± 0.36 g gallic acid eqs/100g dry weight
Flavonoid content	5.15 ± 0.33 g quercetin eqs/100g dry weight
Antioxidant capacity	1379 ± 40 mmoles TROLOX eqs/100g dry weight
Total reducing sugars	57.2 g gluose eqs/100g dry weight
Protein content	0.84 ± 0.07 g BSA eqs/100 g dry weight

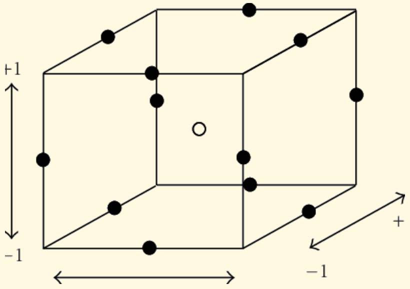
Box Behnken design

Experiment	Independent variables			Dependent variables		
	X_1	X_2	X_3	Y_1	Y_2	Y_3
1	20	0.16	10	137.50±0.38	0.172±0.016	-38.10±0.67
2	80	0.16	10	125.10±1.94	0.116±0.016	-42.20±1.04
3	20	0.48	10	143.90±1.42	0.128±0.015	-37.50±0.70
4	80	0.48	10	162.80±1.67	0.148±0.012	-28.50±0.53
5	20	0.32	5	135.60±0.57	0.182±0.021	-41.30±0.69
6	80	0.32	5	167.10±0.23	0.121±0.018	-41.50±1.23
7	20	0.32	15	157.60±2.08	0.127±0.014	-40.50±1.60
8	80	0.32	15	161.50±1.16	0.085±0.019	-42.30±0.29
9	50	0.16	5	95.95±0.54	0.230±0.018	-44.40±0.15
10	50	0.48	5	138.40±0.56	0.169±0.019	-40.30±0.38
11	50	0.16	15	126.10±1.34	0.186±0.003	-44.30±0.44
12	50	0.48	15	130.30±1.31	0.199±0.026	-43.20±0.10
13	50	0.32	10	126.80±0.67	0.160±0.008	-44.60±0.44
14	50	0.32	10	143.00±2.30	0.159±0.013	-45.20±0.51
15	50	0.32	10	127.70±2.98	0.144±0.005	-38.90±0.78

X_1: Temperature (°C)

X_2: [Extract] (mg/mL)

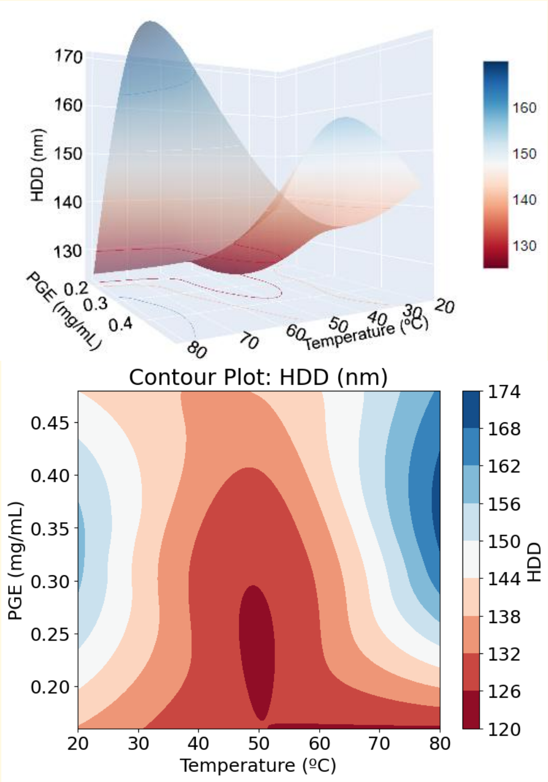
X_3: [$AgNO_3$] (mM)



Y_1: HDD (nm)

Y_2: PDI

Y_3: Zeta potential (mV)



↓ HDD at moderate Tª and ↓ [PGE]

Box Behnken design

Min BB Enero 2024 RDP v1

Archivo Editar Ver Insertar Entorno de ejecución Herramientas Ayuda

Comandos + Código + Texto ▷ Ejecutar todas

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os.chdir(ruta_trabajo)
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Mounted at /googledrive
```

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df = pd.read_excel("Data_10-01-2024.xlsx",sheet_name="Hoja1")
df.head(30)
```
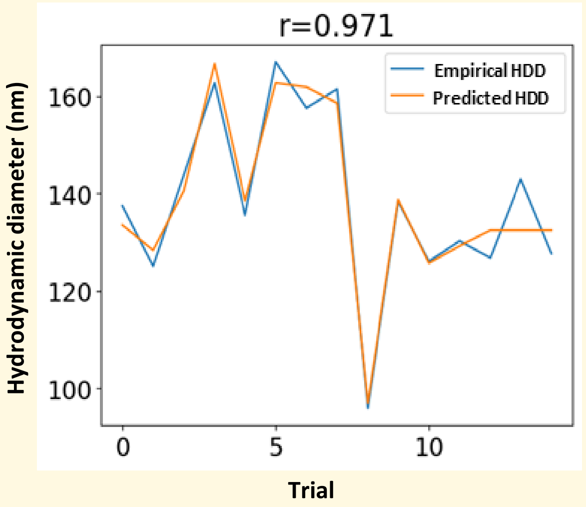
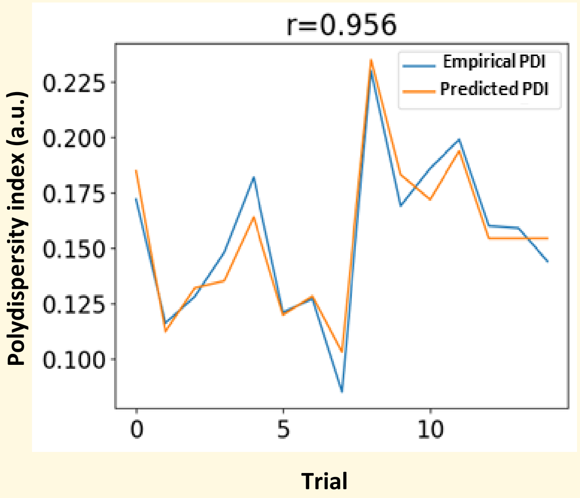

	Temperature	PGE	AgNO3	HDD	HDD_standard_deviation	PDI	PDI_standard_deviation	ZP	ZP_standard_deviation
0	20	0.16	10	88.5	7.2	0.172	0.016	-38.1	0.656
1	80	0.16	10	82.8	4.8	0.116	0.016	-42.2	1.040
2	20	0.48	10	101.4	1.9	0.128	0.015	-37.5	0.700
3	80	0.48	10	105.7	2.9	0.148	0.012	-28.5	0.529
4	20	0.32	5	88.2	9.6	0.182	0.021	-41.3	0.693
5	80	0.32	5	118.0	9.9	0.121	0.018	-41.5	1.230
6	20	0.32	15	111.4	6.4	0.127	0.014	-40.5	1.600
7	80	0.32	15	124.6	6.1	0.085	0.019	-42.3	0.289
8	50	0.16	5	87.0	0.6	0.230	0.018	-44.4	0.153
9	50	0.48	5	89.0	9.5	0.169	0.019	-40.3	0.379
10	50	0.16	15	68.4	1.9	0.186	0.003	-44.3	0.436
11	50	0.48	15	81.6	3.5	0.199	0.026	-43.2	0.100
12	50	0.32	10	76.7	6.7	0.160	0.008	-44.6	0.436
13	50	0.32	10	94.8	2.0	0.159	0.013	-45.2	0.513
14	50	0.32	10	84.2	2.8	0.144	0.005	-38.9	0.781

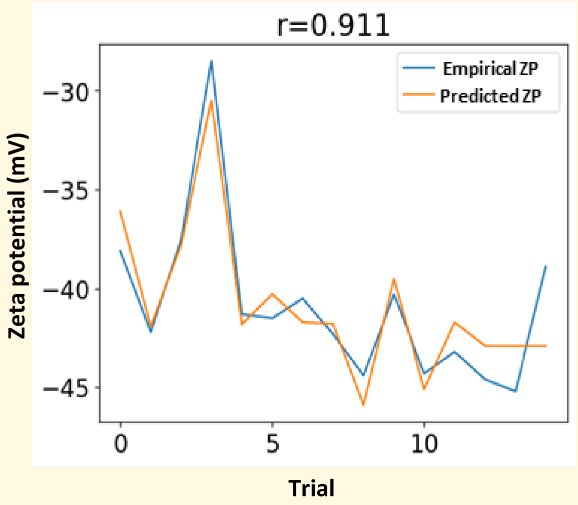
ver datos iniciales

Developed by Prof. Fernando Borrás

Box Behnken design







	Response	Predicted value	Experimental value
AgNPs-OPT	HDD (nm)	131.3	130.3±12.0
	PDI	0.147	0.149±0.018
	ZP (mV)	-46.0	-48.3±0.6
AgNPs-HDD	HDD (nm)	96.7	96.4±0.5
AgNPs-PDI	PDI	0.092	0.115±0.006
AgNPs-ZP	ZP (mV)	-46.3	-44.6±1.8

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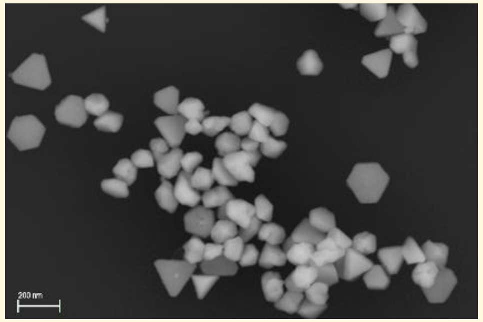
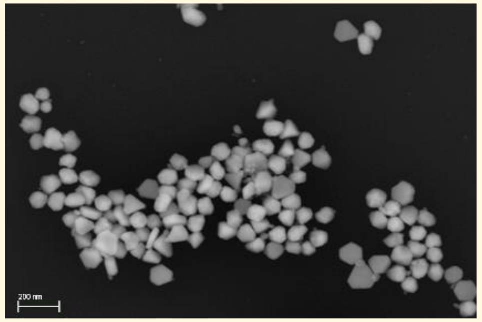
AgNPs characterization

FESEM

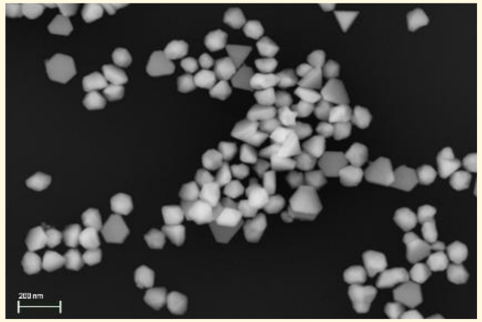
AgNPs-OPT



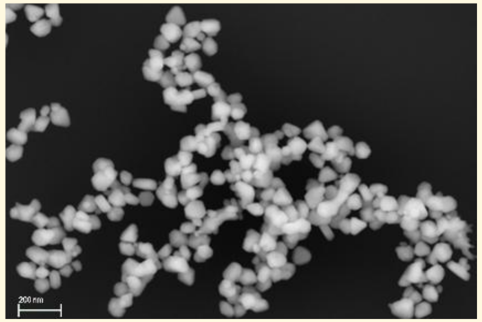
AgNPs-HDD



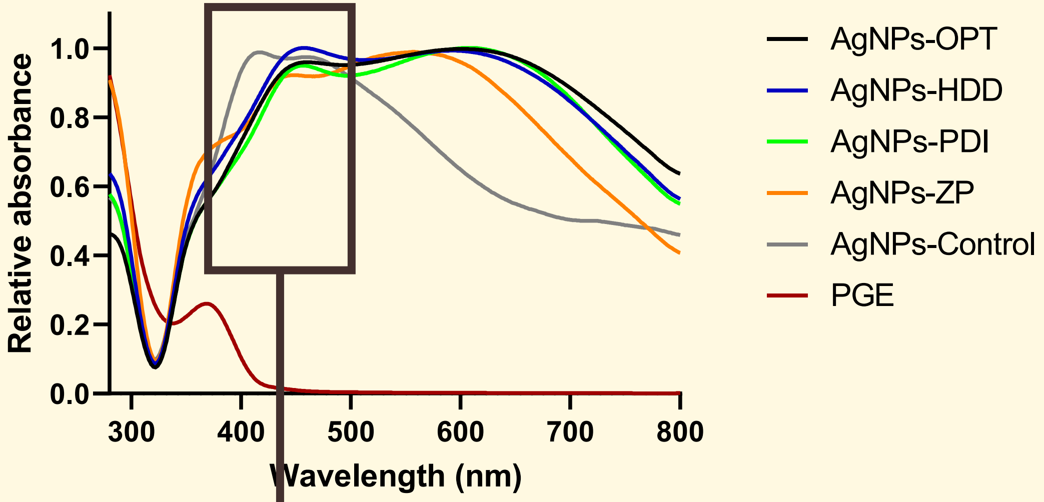
AgNPs-PDI



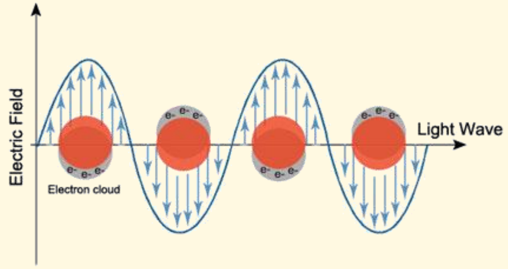
AgNPs-ZP



UV-vis spectroscopy



Surface Plasmon Resonance band

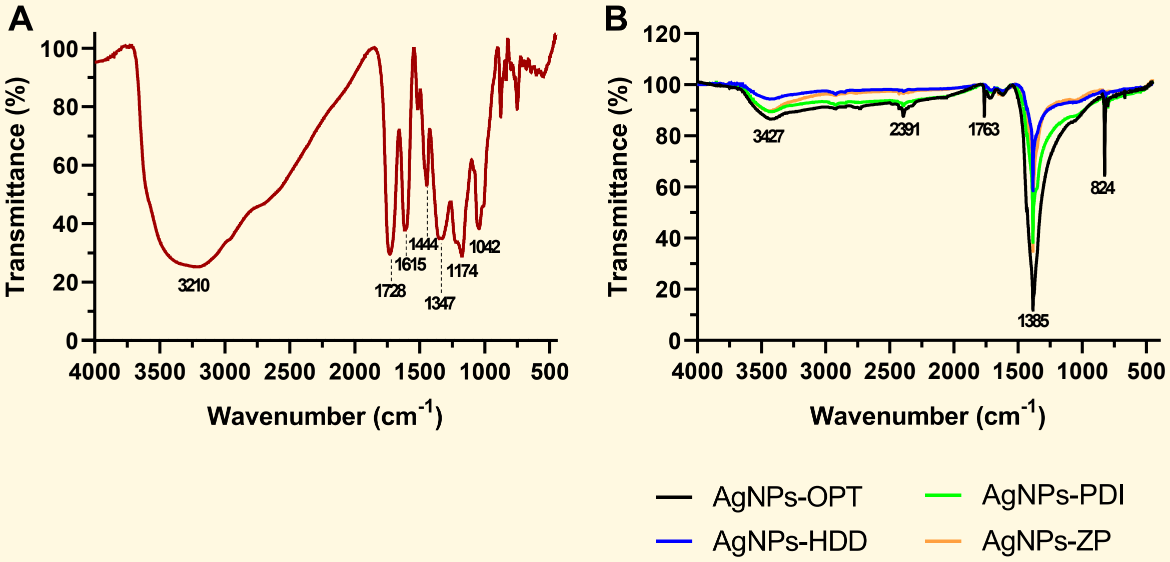


AgNPs characterization

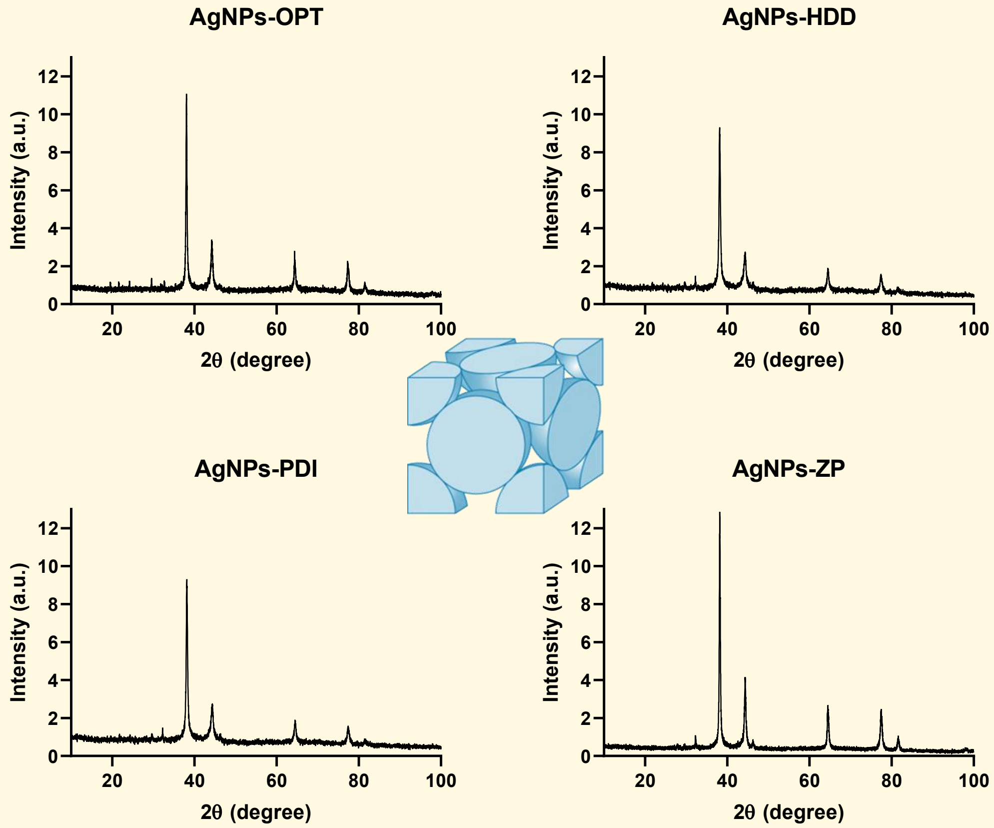
FTIR spectroscopy

Pomegranate peel extract

AgNPs



X-ray diffraction



Antibacterial activity

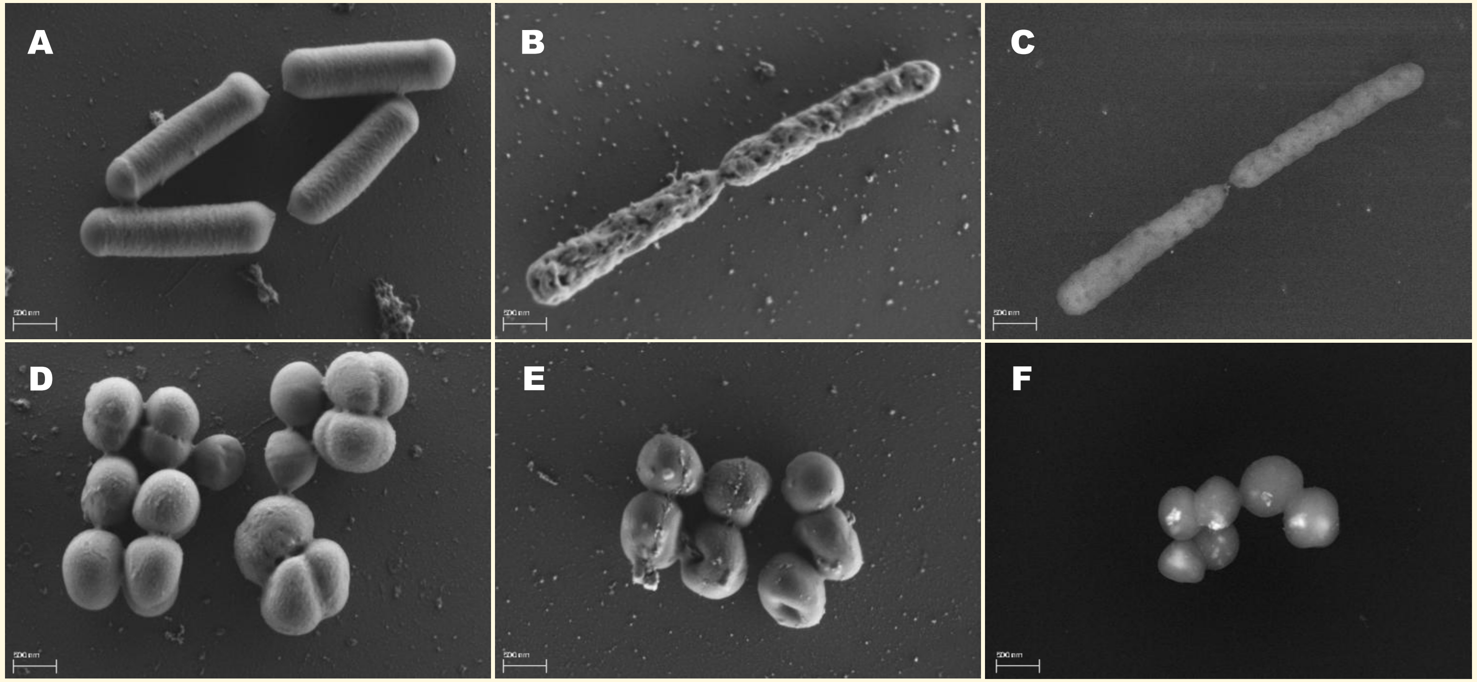
MIC (μg/mL)

	AgNPs-OPT	AgNPs-HDD	AgNPs-PDI	AgNPs-ZP
E. coli	5.0	2.5	5.0	2.5
S. aureus	2.5	2.5	5.0	10

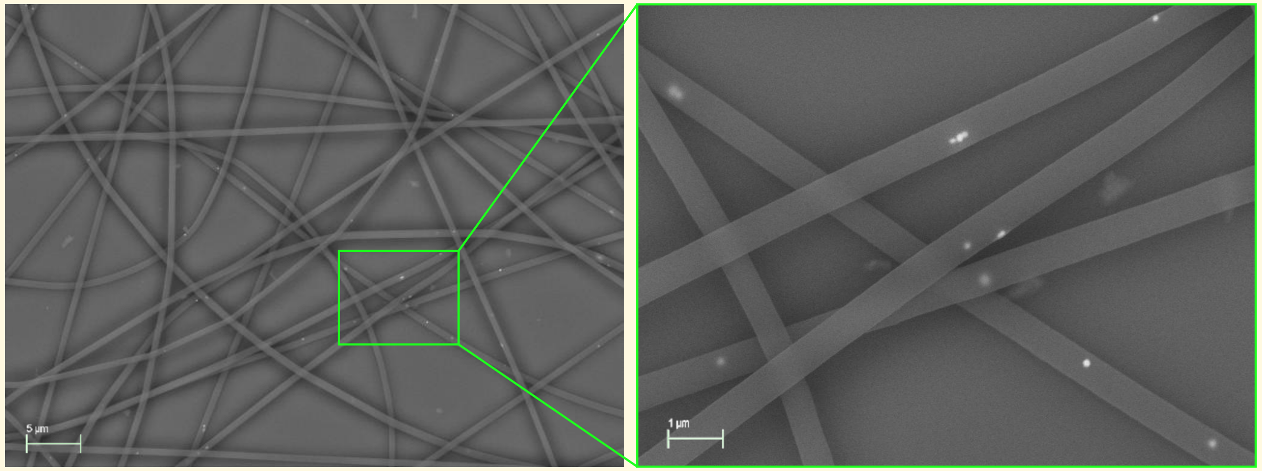
Control **Treated (surface)** **Treated (inside)**

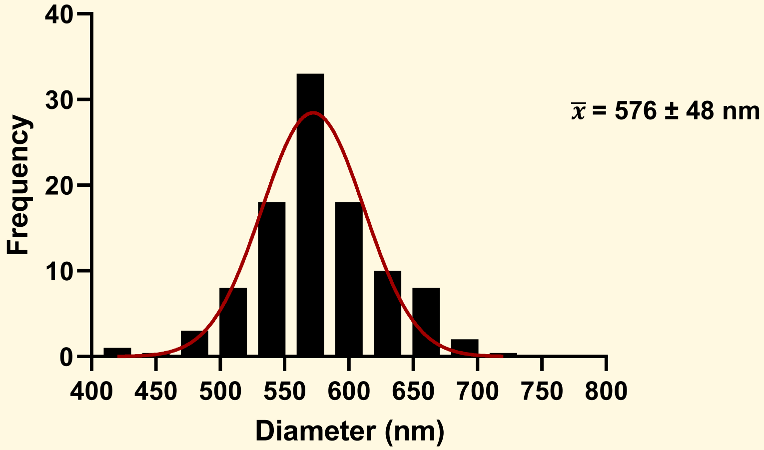
E. coli

S. aureus



Incorporation into nanofibers





MIC AgNPs

E. coli	*S. aureus*
5 µg/ml	2,5 µg/ml

10 µg/ml

MIC AgNPs in nanofibers

Conclusions

- **AgNPs** were **synthesized** using a **green synthesis** method with **pomegranate peel** extract.
- The synthesis was optimized using a **Box–Behnken Design (BBD)**, allowing control of key nanoparticle properties: **size**, **polydispersity index** and **zeta potential**.
- Characterization confirmed the successful formation of **anisotropic AgNPs**.
- The synthesized AgNPs showed effective and differential **antibacterial activity** against ***E. coli*** and ***S. aureus***.
- Optimized AgNPs were successfully incorporated into **nanofibers**, **retaining** part of their **antimicrobial activity**.

Conclusions

Research Article

An Innovative Approach Based on the Green Synthesis of Silver Nanoparticles Using Pomegranate Peel Extract for Antibacterial Purposes

Rocío Díaz-Puertas,[1] **Francisco J. Álvarez-Martínez**,[1] **Enrique Rodríguez-Cañas**,[1] **Fernando Borrás**,[2] **Artur J. M. Valente**,[3] **José A. Paixao**,[4] **Alberto Falcó**,[5] **and Ricardo Mallavia**[1]

[1]*Institute of Research, Development and Innovation in Healthcare Biotechnology in Elche (IDiBE), Miguel Hernández University, Elche 03202, Alicante, Spain*
[2]*Statistics and Operative Research Department, Miguel Hernández University, Elche 03202, Alicante, Spain*
[3]*Department of Chemistry, University of Coimbra, Coimbra 3004-535, Portugal*
[4]*Department of Physics, University of Coimbra, Coimbra 3004-516, Portugal*
[5]*Fish Pathology Group, Institute of Aquaculture Torre de La Sal-Spanish National Research Council (IATS-CSIC), Cabanes 12595, Castellón, Spain*

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Green Synthesis of Silver Nanoparticles Using Pomegranate Peel Extract: An Optimized Approach for Antibacterial Applications

Thank you!

¡Gracias!

Dr. Rocío Díaz-Puertas

r.diaz@umh.es

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