

Antimicrobial activity of Iron oxide nanoparticles (IONPs) functionalized with anthocyanin extracted from blackcurrants (*Ribes nigrum*)

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AIM OF THE WORK

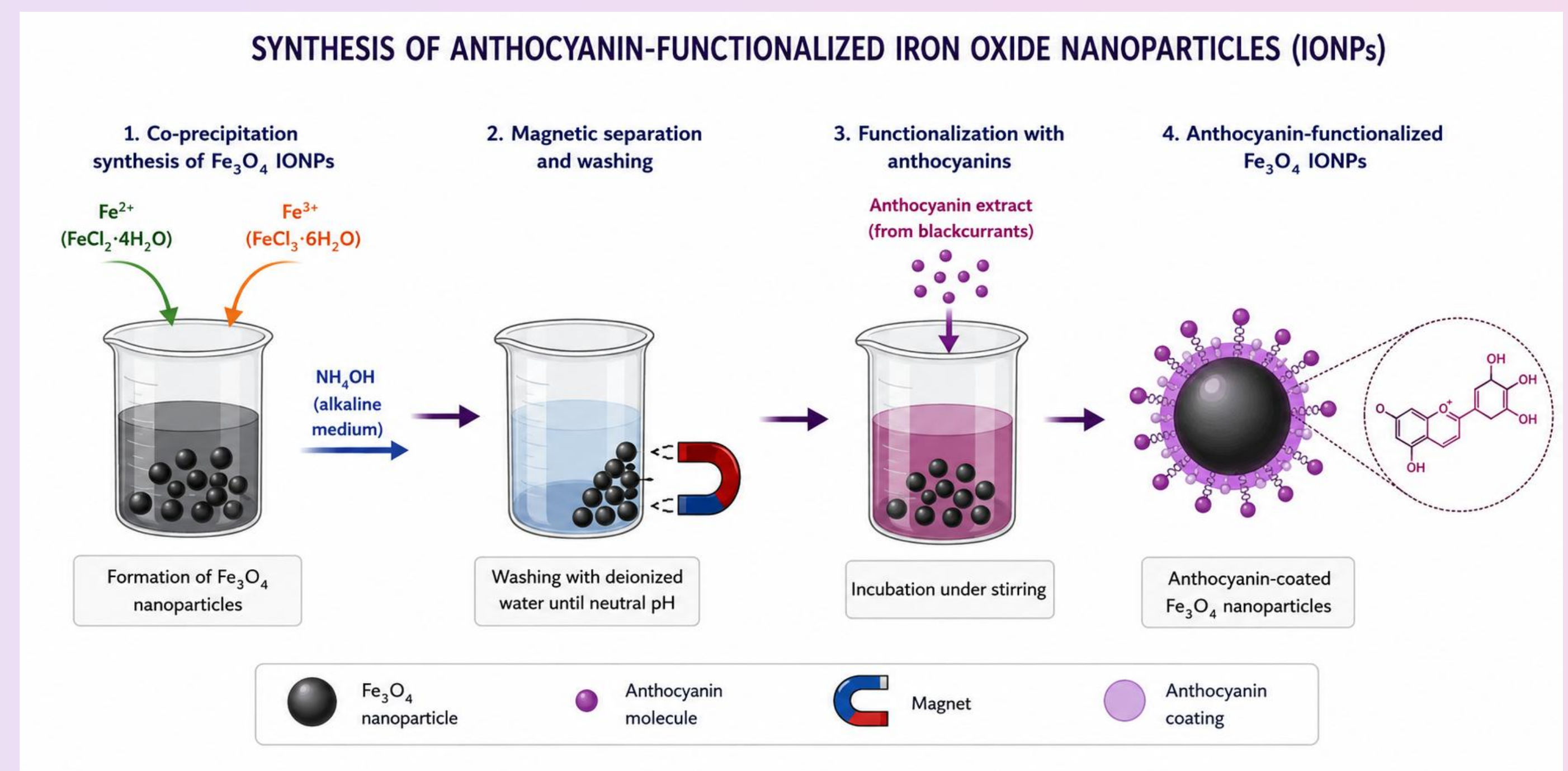
- Synthesis of anthocyanin-functionalized magnetic iron oxide (Fe_3O_4) nanoparticles (IONPs) using anthocyanins extracted from blackcurrants (*Ribes nigrum*).
- Investigation of their antimicrobial activity against the Gram-negative strains *Escherichia coli* ATCC 25922 and multidrug-resistant (MDR) *E. coli* O26:H11, as well as the Gram-positive strains *Enterococcus faecalis* ATCC 29212 and MDR *E. faecalis* C.E.64.

KEYPOINTS

- Phytochemical-functionalized iron oxide nanoparticles were successfully engineered.
- The nanovectors demonstrated consistent antibacterial activity against both Gram-negative and Gram-positive bacterial strains.
- The nano-conjugates effectively protected the active compounds from pH-induced degradation and protein corona formation in biological media.

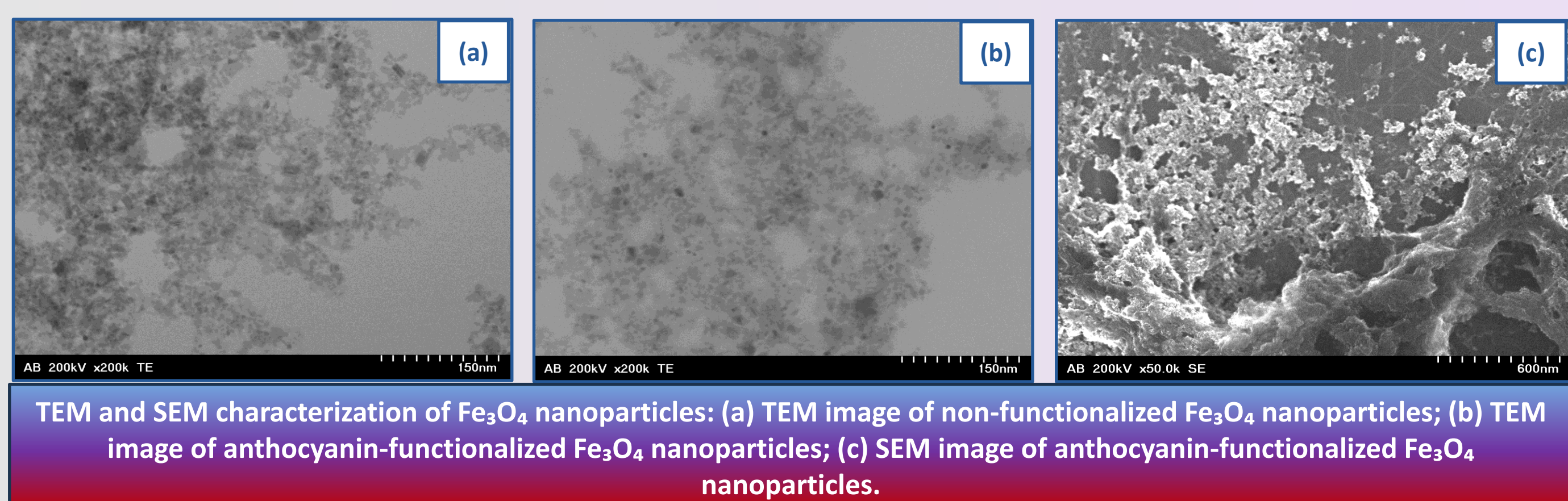
PREPARATION METHOD

- IONPs were synthesized using the co-precipitation method.
- Functionalization was achieved by adsorption of anthocyanins extracted from blackcurrants (*Ribes nigrum*) onto the surface of the nanoparticles.



RESULTS & DISCUSSION

MORPHOLOGICAL CHARACTERIZATION

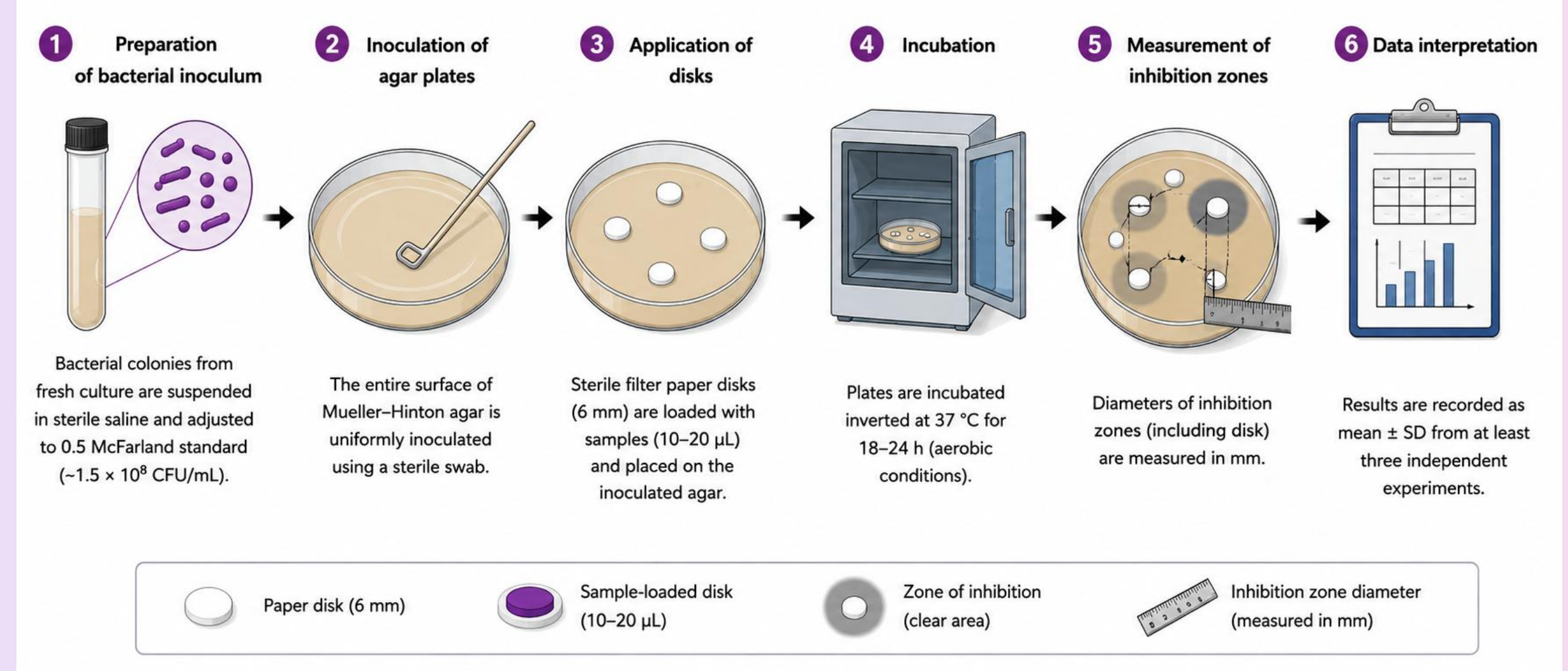


The TEM and SEM images indicate that anthocyanin functionalization does not induce nanoparticle aggregation; on the contrary, the particles appear more uniformly distributed and better dispersed compared to the non-functionalized Fe_3O_4 sample.

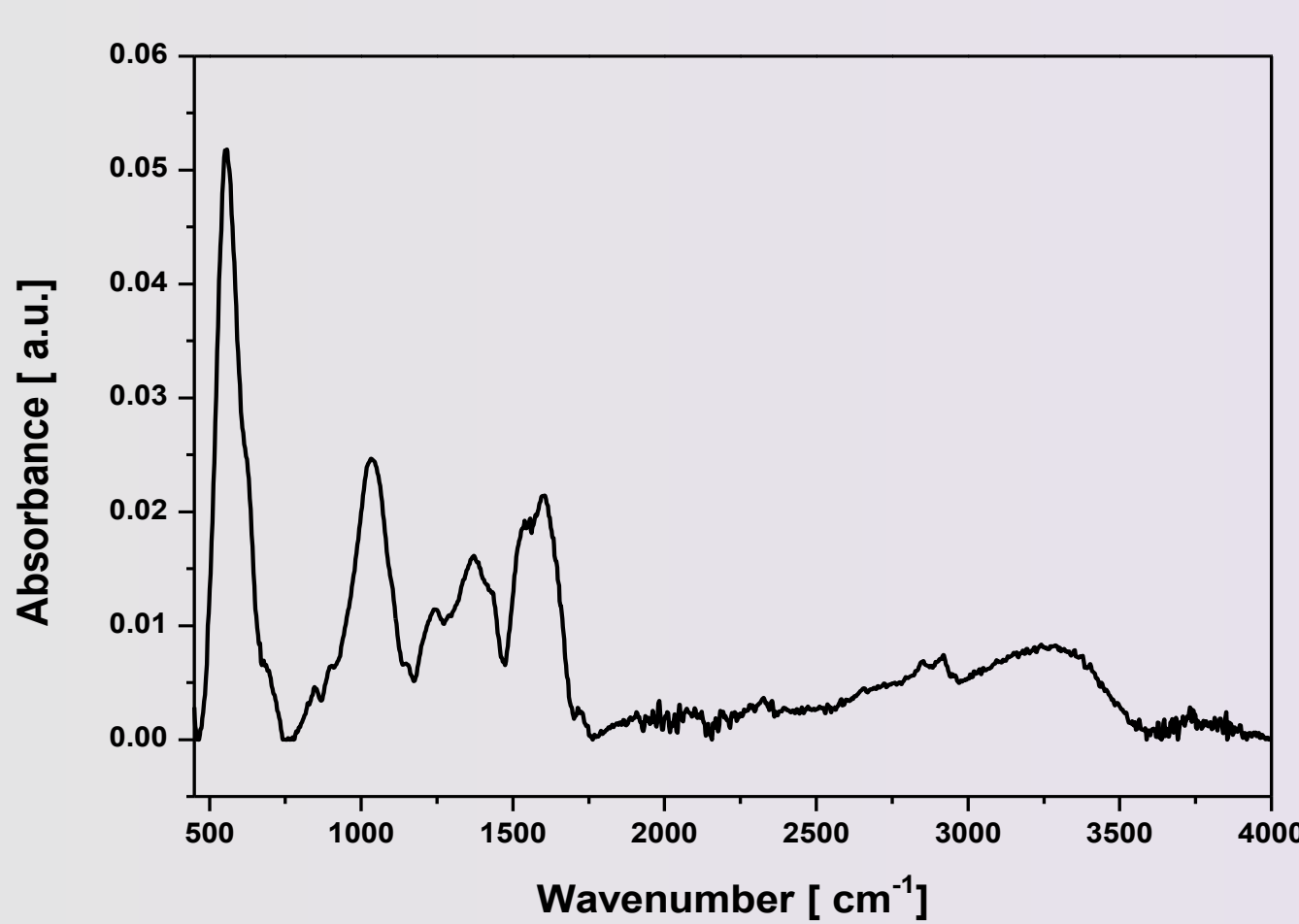
ANTIMICROBIAL ESSAY

- The antimicrobial activity of anthocyanin-functionalized IONPs (113 mg/mL) was evaluated and compared with free anthocyanin extract (1,550.32 mg/mL) and non-functionalized IONPs (576.5 mg/mL) used as controls.
- Antibacterial efficacy was assessed using the disk diffusion method on Nutrient Agar against two Gram-positive and two Gram-negative bacterial strains.

ANTIMICROBIAL ASSAY – DISK DIFFUSION METHOD



STRUCTURAL CHARACTERIZATION



Characteristic absorption bands were assigned to:

- magnetite**
- $\sim 580 \text{ cm}^{-1}$ – Fe–O stretching vibration
- anthocyanin**
- $1000\text{--}1200 \text{ cm}^{-1}$ – C–O and C–O–C vibrations
- $1500\text{--}1650 \text{ cm}^{-1}$ – aromatic C=C vibrations
- $3200\text{--}3400 \text{ cm}^{-1}$ – O–H stretching vibrations

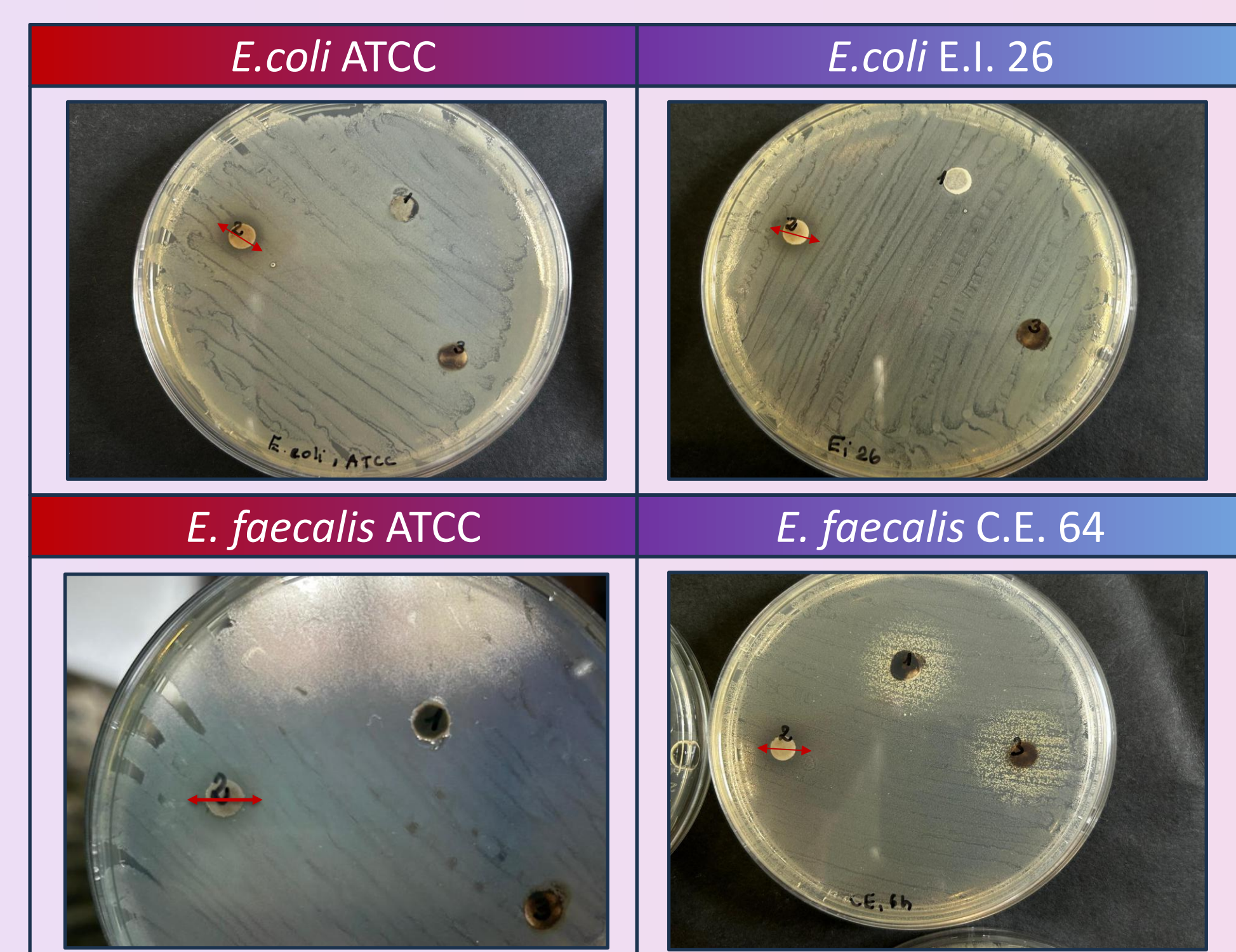
The coexistence of Fe–O and anthocyanin-related bands indicates the successful immobilization of anthocyanin molecules on the Fe_3O_4 nanoparticle surface.

CONCLUSIONS

- Anthocyanin-functionalized IONPs exhibited broad-spectrum antibacterial activity.
- Nano-functionalization generated a synergistic effect, significantly enhancing the antibacterial performance compared to free anthocyanins or bare IONPs.

FUTURE PERSPECTIVES

- Optimization of magnetic targeting capabilities
- Development of linker-mediated functionalization strategies
- Determination of minimum inhibitory concentrations (MICs)
- Optimization of antimicrobial testing protocols



- Anthocyanin-functionalized nanovectors exhibited antibacterial activity against both Gram-positive and Gram-negative bacteria, with inhibition zones of 7–10 mm.
- Reference strains were slightly more susceptible than MDR clinical isolates, reflecting their lower intrinsic resistance.
- Neither free anthocyanins nor bare IONPs showed antibacterial activity, demonstrating a strong synergistic effect upon functionalization.
- Nano-functionalization enhanced anthocyanin stability and bioavailability, resulting in improved antibacterial performance.