Photosensitizer-functionalized silver nanoparticles as potential agents for antibacterial photodynamic therapy

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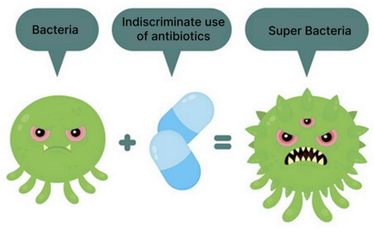
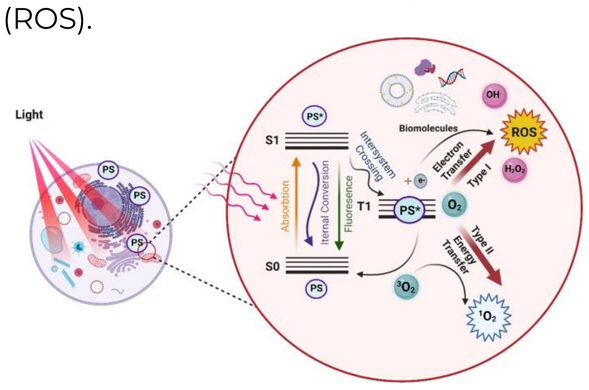
INTRODACTION

The global spread of **antibiotic-resistant** bacteria, driven by overuse in medicine and agriculture, has become a critical public health challenge, resulting in prolonged treatments and increased mortality. Immunocompromised patients are particularly vulnerable, as antibiotic resistance complicates **wound** healing and raises the risk of severe infections.



Antibacterial photodynamic therapy (aPDT) offers a promising alternative by utilizing light-activated **photosensitizers** to generate bactericidal reactive oxygen species (ROS).

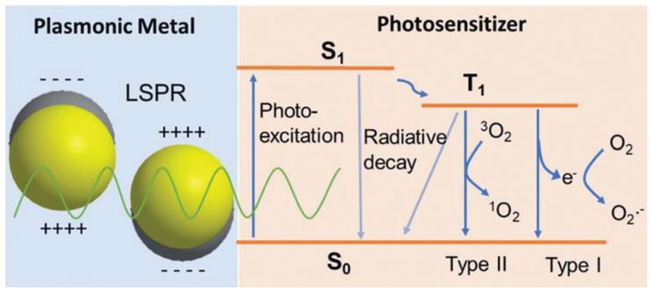


Silver nanoparticles (AgNPs) further enhance antibacterial action through multiple mechanisms, including Ag^+ ion release, ROS generation, and direct physical damage to bacterial cells.

The **combination** of aPDT and AgNPs presents a **synergistic strategy** to overcome antibiotic resistance, potentially revolutionizing antimicrobial treatment.

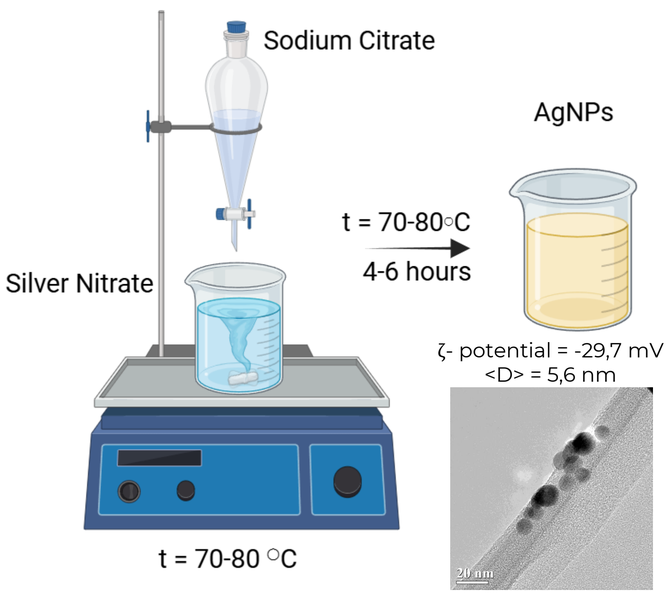
The aim of the work

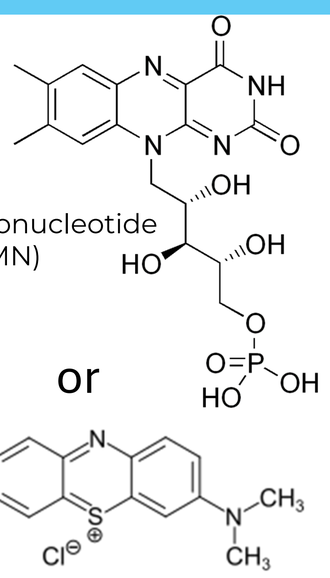
to prepare antibacterial complexes of silver nanoparticles with photosensitizers – flavin mononucleotide (FMN) and methylene blue (MB)



RESULTS AND DISCUSSION

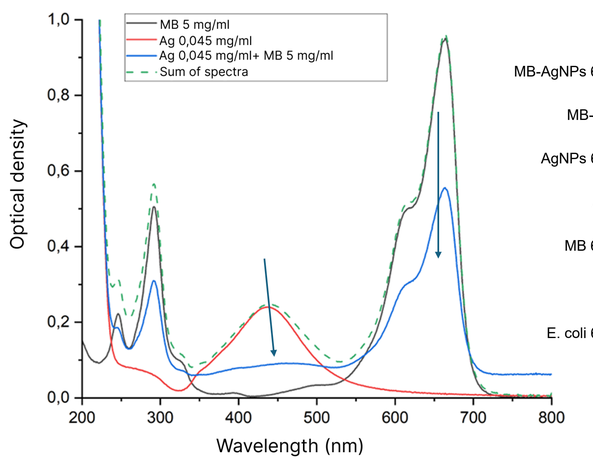
Synthesis and characterization

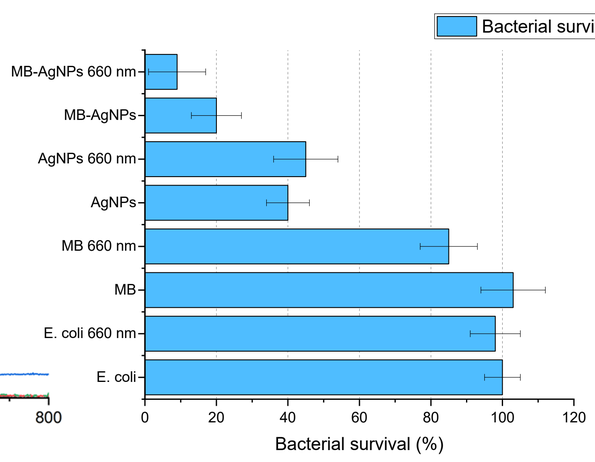




AgNPs demonstrated high colloidal stability and a local surface plasmon resonance (LSPR) peak at 435 nm. Citrate ions served as both the reducing agent and stabilizer for AgNPs.

MB-AgNPs complex





The formation of a complex between AgNPs and MB is accompanied by a bathochromic shift in plasmon resonance, an increase in size, and the formation of aggregates

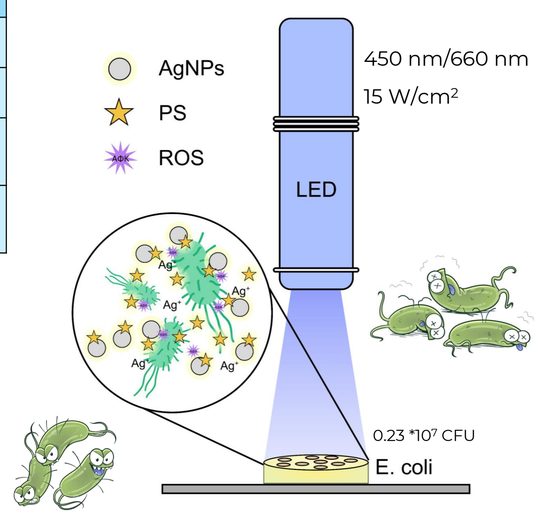
The production rate of OH radicals decreased by 5 times. AgNPs in combination with MB reduce the production of hydroxyl radicals (ROS) due to the possible formation of MB dimers on the surface of AgNPs

	AgNPs	AgNPs-MB	AgNPs-FMN
Size	5,6 nm	13,5 nm	6,5 nm
Zeta-potential	-29,7 mV	- 18,4 mV	- 27,4 mV
Photodegradation time	–	690,1 sec vs. 594,9 sec ↑	31,6 sec vs. 22,6 sec ↑
Inactivation of bacteria	Medium	High ↑	High ↑

Photodegradation time increases for complexes due to possible light shielding, stabilization of PS during adsorption on AgNPs

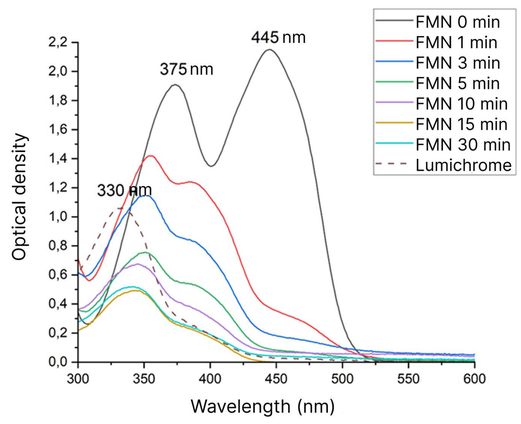
The complexes demonstrated higher phototoxicity compared to samples containing only AgNPs or MB/FMN

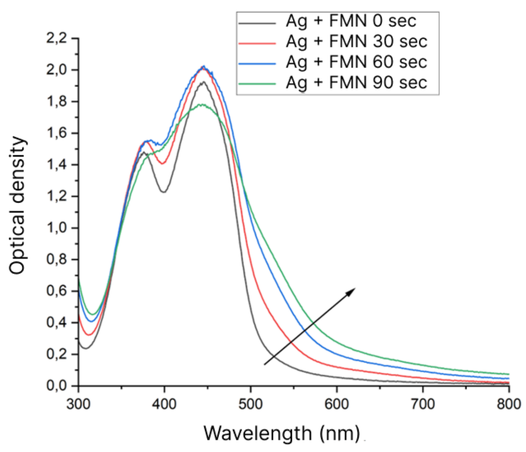
aPDT *in vitro*

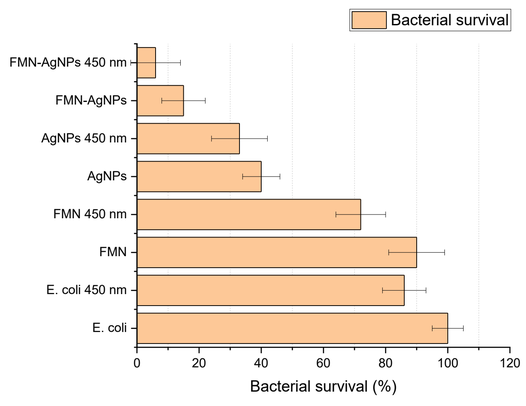


Antibiotic-resistant *E. coli* (BL21(DE3)) expressing the fluorescent protein mKate

FMN-AgNPs complex







Under blue light irradiation (450 nm) FMN photodegradates to photoproducts (lumichrome, etc.). In the complex, lumichrome is not formed by blue light irradiation.

The complex is detected by the formation of an absorption band at 530 nm.

The rate of production of OH radicals increased by 3 times. AgNPS contribute to an increase in the amount of ROS (OH·) generated by FMN when irradiated with blue light

CONCLUSIONS

The physicochemical characterization of the AgNPs-photosensitizer complexes revealed the potential to modulate the optical properties of the photosensitizers (FMN and MB) through interaction with AgNPs. These nanoparticles provide photoprotective properties. Both complexes showed superior bactericidal activity compared to individual components. The engineered AgNPs-photosensitizer complexes exhibit significant potential for clinical PDT applications, particularly in eradicating drug-resistant infections. The study provides a foundation for further development of nanoparticle-based photosensitizing systems for antimicrobial applications.

Acknowledgments

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