NANOBIOTECHNOLOGY OF PHOTOSYNTHETIC MICROORGANISMS FOR SUSTAINABLE DEVELOPMENT: CONTROLLED OXIDATIVE STRESS AND METABOLIC RESPONSES

Liliana CEPOI*, Ludmila RUDI, Tatiana CHIRIAC, Svetlana CODREANU
Institute of Microbiology and Biotechnology, Technical University of Moldova, Chisinau, Republic of Moldova
*Corresponding author: liliana.cepoi@imb.utm.md

https://doi.org/10.52757/bsd26.26

Background: Interactions between engineered nanoparticles (NPs) and photosynthetic microorganisms represent a rapidly developing field at the interface of nanotechnology and microbial biotechnology. Metal and metal oxide nanoparticles can act as both stressors and modulators of cellular metabolism, inducing oxidative stress responses that may lead to either growth inhibition or adaptive metabolic redirection.
Aim of the study: The study aims to elucidate the physiological and biochemical responses of selected photosynthetic microorganisms (cyanobacteria and microalgae) to exposure to engineered nanoparticles, with a focus on oxidative stress modulation and its impact on biomass productivity and metabolite accumulation.
Materials and methods: Model strains of cyanobacteria and microalgae (e.g., *Arthrospira platensis, Nostoc linckia, Haematococcus lacustris*) were cultivated under controlled laboratory conditions and exposed to metal and metal oxide nanoparticles of defined sizes and concentrations. Growth parameters, pigment content (chlorophylls, carotenoids), and oxidative stress markers were monitored. Spectrophotometric and biochemical assays were used to assess cellular responses, and comparative analyses between treatments and controls were performed.
Results: Exposure to engineered NPs induced dose- and size-dependent responses across all tested strains. At higher concentrations, NPs inhibited growth, increased oxidative stress, degraded pigments, and impaired photosynthetic activity. In contrast, sublethal concentrations triggered hormetic effects, reflected in moderate stimulation of growth and metabolism. Photosynthetic microorganisms activated antioxidant defense mechanisms, leading to increased levels of protective pigments and improved redox balance. In *Haematococcus lacustris*, controlled nanoparticle exposure promoted a shift toward carotenoid biosynthesis, resulting in enhanced astaxanthin accumulation under moderate stress conditions. Cyanobacteria such as *Arthrospira platensis* and *Nostoc linckia* exhibited adaptive responses mediated by extracellular polymeric substances (EPS), which reduced nanoparticle bioavailability and toxicity. Nanoparticle size also influenced biological effects, with smaller particles inducing stronger responses. Overall, the results highlight the dual role of nanoparticles as both stressors and modulators of metabolism, with controlled oxidative stress enhancing the production of valuable metabolites.
Conclusions: The results demonstrate that controlled nanoparticle-induced stress can be exploited as a biotechnological tool to modulate metabolic pathways in photosynthetic microorganisms. Understanding the balance between toxicity and hormesis is essential for developing sustainable biotechnological applications, including high-value metabolite production.
Keywords: nanoparticles, microalgae, cyanobacteria, oxidative stress, hormesis, metabolites.

Acknowledgments: This work was supported by research subprogram 020101 funded by the Ministry of Education and Research of the Republic of Moldova.