INTERACTION MODELS OF ZnO MULTIPOD NANOPARTICLES WITH CYANOBACTERIUM *ARTHROSPIRA PLATENSIS* AND RED MICROALGA *PORPHYRIDIUM PURPUREUM*

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Background: Zinc oxide-based nanomaterials exhibit distinct physicochemical properties that influence their interactions with biological systems. In microalgae and cyanobacteria, these interactions exert effects that are strongly dependent on morphology, concentration, and the timing of application relative to the culture's physiological state.

Aim of the study: To investigate interaction models of ZnO multipod nanoparticles with cyanobacterium *Arthrospira platensis* and red microalga *Porphyridium purpureum*, focusing on metabolic response and oxidative stress.

Material and methods: *Arthrospira platensis* and *Porphyridium purpureum* cultures were grown under controlled conditions and exposed to ZnO multipod nanoparticles at concentrations ranging from 0.1 to 30 mg/L. Nanoparticles were applied at different growth stages (lag, exponential, and pre-stationary/tardo-exponential phases). Biomass, biochemical composition (proteins, carbohydrates, lipids, photosynthetic pigments, and phycobiliproteins), and oxidative stress marker (MDA) were assessed. Statistical analysis was performed using Student's t-test ($p < 0.05$).

Results: The interaction of ZnO multipod nanoparticles with microalgal systems follows a general dose-dependent model, differentiated according to the cultures' physiological state. In *Arthrospira platensis*, the response is phase-dependent. It follows a sequence of patterns: an initial adaptation model characterized by minor changes at low doses, followed by a compensatory model in the exponential phase, defined by the accumulation of carbohydrates and lipids and a reduction in phycobiliproteins, and finally an advanced oxidative stress model marked by decreased protein content and increased lipid peroxidation markers. In *Porphyridium purpureum*, the interaction is predominantly dose-dependent and less influenced by growth phase, characterized by an early and persistent oxidative stress model, with lipid reduction, pigment variations, and a continuous increase in malondialdehyde levels. At low doses, a moderate metabolic adjustment model is observed, whereas at high concentrations, phycobiliproteins undergo progressive degradation.

Conclusion. The data obtained indicate that the interaction between ZnO multipod nanoparticles and microalgae and cyanobacteria follows a sequence of functional patterns: initial adaptation → compensatory response → advanced/persistent oxidative stress, characterized by correlated changes in biomolecules and oxidative stress markers. These results support the controlled use of nanomaterials to modulate microalgal metabolism, provided that the applied concentrations are strictly optimized.

Keywords: ZnO nanoparticles, multipod morphology, microalgae, *Arthrospira platensis*, *Porphyridium purpureum*, oxidative stress, metabolic response.

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