

## EFFECTS OF SILVER NANOPARTICLES ON BIOMASS, PROTEIN, AND CARBOHYDRATE ACCUMULATION IN *HAEMATOCOCCUS LACUSTRIS* DURING THE GREEN GROWTH PHASE

Liliana CEPOI\*<sup>ID</sup>, Vera MISCU<sup>ID</sup>, Ana VALUȚA<sup>ID</sup>, Ecaterina PLÂNGĂU<sup>ID</sup>, Iulia IAȚCO<sup>ID</sup>, Valeriu RUDIC<sup>ID</sup>  
Institute of Microbiology and Biotechnology, Technical University of Moldova, Chisinau, Republic of Moldova

\*Corresponding author: [liliana.cepoi@imb.utm.md](mailto:liliana.cepoi@imb.utm.md)

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**Aim of the study:** Evaluation of the effects of citrate-stabilized AgNPs (10 nm and 20 nm), applied at different concentrations, on biomass accumulation, protein content, and carbohydrate content during the green growth phase of *Haematococcus lacustris* strain CNMN-AV-05.

**Materials and methods:** Microalgal cultures were exposed to AgNPs at concentrations ranging from 0.01 to 5 mg/L, applied from the onset of the green growth phase. At the end of this stage, the following parameters were determined: biomass (g/L), protein content (% of dry biomass), and carbohydrate content (% of dry biomass). Statistical significance of differences compared to the control was assessed using Student's t-test ( $p < 0.05$ ).

**Results:** Exposure to AgNPs induced concentration- and size-dependent effects on all analyzed parameters. Low concentrations of 10 nm AgNPs (0.01-0.1 mg/L) stimulated biomass accumulation by 14.12-16.23%, while concentrations of 0.5-1 mg/L resulted in more pronounced increases (25.94-27.95%). 20 nm AgNPs produced biomass increases of 14.40% and 27.47% within the stimulatory concentration ranges. In contrast, the highest concentration (5 mg/L) exerted an inhibitory effect, reducing biomass by 29.39-32.75% compared to the control. Protein content increased at all tested concentrations, regardless of nanoparticle size. For 10 nm AgNPs, increases ranged from 8.54% to 15.94%, while 20 nm AgNPs induced higher increases of 13.98-24.88%, with maximum values recorded at 0.1-1 mg/L. Carbohydrate content showed the greatest change among the biochemical parameters. For 10 nm AgNPs, concentrations of 0.05-1 mg/L led to increases of 28.13-64.74%, while extreme concentrations (0.01 and 5 mg/L) resulted in more moderate increases (16.10% and 16.60%, respectively). 20 nm AgNPs induced significant carbohydrate accumulation across the 0.05-5 mg/L range, with the greatest increases observed at 0.5 and 1 mg/L (62.03% and 68.13%, respectively). Overall, a hormetic response was observed, characterized by stimulation at low concentrations and inhibition at high concentrations. Effects were stronger for 20 nm AgNPs, particularly for proteins and carbohydrates.

**Conclusions:** This study demonstrates that controlled application of AgNPs can enhance productivity and stimulate biomolecular biosynthesis in *Haematococcus lacustris* biotechnology, with effects that depend on both concentration and nanoparticle size.

**Keywords:** AgNPs, *Haematococcus lacustris*, biomass, proteins, carbohydrates, hormesis.

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