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Growth and photosynthetic energy transduction efficiency of the green algae *Chlorella vulgaris* under the treatment by copper nanocarboxylates

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Copper (Cu) is essential for plant metabolism; however its higher concentrations exert toxic effects, the range of physiological Cu concentrations being rather narrow. The novel forms of Cu-containing additives are nanoaquachelates, the nanoparticles with the molecules of water and/or carboxylic acids as ligands. The aim of the present research was to study the effects of copper nanoaquachelates carboxylated with citric acid [1] on the growth rates and efficiency of photochemical reactions of the green algae *Chlorella vulgaris* Beijer that are widely used in biotechnology.

C. vulgaris was grown at 25–26°C in 1000 mL Erlenmeyer flasks each containing 400 mL of liquid mineral medium, illuminated continuously with warm white fluorescent lamps providing 40–42 μmol m^{-2} s^{-1} photosynthetic photon flux density (PPFD), and stirred by shaking two times a day. The addition of 0.67–4 mg L^{-1} of copper nanoparticles resulted in the increase in dry mass by ca. 20%, however their concentrations ranging from 20 to 40 mg L^{-1} strongly inhibited algal growth after the 12^{th} day of cultivation. The addition of 2–4 mg L^{-1} of copper nanocarboxylates caused the evident initial increase in maximal quantum yield of Photosystem II photochemistry (F_v/F_m) and maximal quantum yield of Photosystem II photochemistry at a given PPFD (F_v'/F_m'). Photochemical quenching coefficient (q_P) was reduced after 24 days of growth with copper nanoparticles, and the alterations mentioned affected the overall quantum yield of linear electron flux through Photosystem II.

Thus, the utilization of copper nanoparticles carboxylated with citric acid at the concentrations of 0.67–4 mg L^{-1} stimulates growth of *Chlorella vulgaris* by ca. 20% and therefore may be recommended for further investigations aimed to improve the accumulation of *Chlorella* biomass.

1. *Kosinov M. V., Kaplunenko V. H.* [Method of obtaining the hydrated and carbonated nanoparticles electroimpulse nanotechnology of obtaining hydrated and carbonated nanoparticles] // UA Patent 35582.-25.09.2008.-Bul. N 18. [Ukr.]