The influence of functionalized magnetic nanostructures on the generation of reactive oxygen species in biological media

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Functionalized magnetic nanostructures are often intended for theranostic applications, serving multiple functions, e.g., as contrast agents in magnetic resonance imaging, magnetic hyperthermia mediators or drug carriers. It is therefore highly important to investigate the interaction of iron oxide nanoparticles with the biological environment and check whether they can contribute to the generation of reactive oxygen species (ROS). Radicals can damage healthy tissues, but they could also help eliminate cancer cells.

Electron spin resonance spectroscopy (ESR) is a proven method for the detection and identification of reactive oxygen species. Furthermore, ESR is successfully used in the study of iron oxide nanoparticles to identify the material of their core, determine magnetic properties [1], investigate the influence of the polymer coating on the interactions of nanoparticles with the biological environment, including whole human blood [2] and even to image spin-labeled nanostructures [3].

Our measurements were performed with a Bruker EPR/ENDOR EMX-10 spectrometer. Due to the fact that free radicals are often short-lived, the spin trapping technique was used for their identification. Relatively stable paramagnetic adducts were formed as a result of the attachment of a specific radical to DMPO or DEPMPO traps. Qualitative and quantitative analysis were performed on the basic of recorded spectra. It was determined, how Fe_3O_4 nanoparticles influence the formation of free radicals in agar phantoms and a baker's yeast cell colony, also in the presence of hydrogen peroxide. It was also examined to what extent the use of PEG or chitosan coating minimizes the risk of the occurrence of radical reactions and whether the presence of sodium ascorbate (antioxidant) in the environment of magnetite nanoparticles contributes to the reduction of the amount of ROS produced in the samples. In addition, the behavior of Fe_3O_4 nanoparticles labeled with 4-Amino-TEMPO and 4-Hydroxy-TEMPO was investigated, and the rate of nitroxide reduction and its role in radical processes in yeast cell suspension were verified.

References:

[1] T. Kubiak, B. Dobosz, Materials 18, 2025, 2841.
[2] T. Kubiak, R. Krzyminiewski, B. Dobosz, et. al., Acta Bio-Opt. Inf. Med. Biomed. Eng., 21 (1), 2015, 9-15.
[3] R. Krzyminiewski, T. Kubiak, B. Dobosz, et. al., Curr. Appl. Phys. 14, 2014, 798-804.

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