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Applications of Biological Magnetic Nanoparticles in Nanobiotechnology

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Extended Abstract

Magnetotactic bacteria (MTB) are a diverse group of aquatics, flagellated Gram-negative prokaryotes that biomineralize magnetosomes [1]. These structures are ferrimagnetic nanocrystals composed of magnetite (Fe_3O_4) or greigite (Fe_3S_4) surrounded by a biological membrane. Magnetosomes are diverse in shape and size and usually aligned in chains along within the cell. These structures allow bacteria to align themselves along the geomagnetic field. This passive alignment associated with MTB active swimming through flagellar propulsion is a behavior called magnetotaxis [2]. Magnetosomes are single-magnetic domains, therefore permanently magnetized. Furthermore, they are chemically pure, crystallographically perfect, biocompatible, and temperature resistant, which are valuable properties in biotechnological applications, distinguishing them from most chemically synthesized magnetic nanoparticles [3]. The natural enveloping membrane is beneficial because it adds colloidal stability to the magnetosome and anchorage sites for functionalizing molecules, including enzymes, genes, antibodies, binding proteins, drugs, and many others. The protein content of the magnetosome's membrane seems to be species-specific, even though the crystals may have similar morphologies. Therefore, it is crucial to stimulate research regarding this topic so that we can understand and direct the best functionalization methods.

Magnetosomes can be extracted from the cell and magnetically purified to be used as an eco-friendly and low-cost nanotool [4]. Their applications have been described in different areas, such as cell separation, drug delivery, DNA and food analysis, enzyme immobilization, bioremediation, contrast enhancement of magnetic resonance imaging, and magnetic hyperthermia [5]. In this meta-analysis review, we aim to gather updated information on the applications of magnetosomes in nanotechnology to understand the relationship among the MTB species, the morphology of magnetosomes, and their areas of application. Hence, a meta-analysis considering the synthetic magnetite nanoparticles and magnetosomes in nanotechnological application is still in progress. The database chosen was Web Of Science and an advanced research code will be written. We expect to find the synthesis methodology of synthetic nanoparticles to be more laborious and high-costing than the magnetosome production, since it usually requires high temperature and a coating step, besides generating chemical waste. Magnetosomes, on the other hand, are an eco-friendly nanotool that already has a biological membrane, which reduces the process cost and time.

Articles regarding MTB date from 1975, but it was not until 1990 that magnetosome's biotechnological application was explored. We observed that magnetosome applications cover approximately 10% of articles published about MTB throughout the years, showing that it is still a vast and unexplored topic. The main MTB used in studies synthesizes cuboctahedral magnetosomes belonging to the *Magnetospirillum* genus, which are strains MSR-1, AMB-1, and MS-1. Nonetheless, recent reports indicate efficient use of the prismatic magnetosomes of *Magnetovibrio blakemorei* strain MV-1^T in magnetic hyperthermia [6] and demonstrated that they display high binding efficiency regarding drug functionalization [4]. Authors have developed a nanoformulation with Amphotericin B, exploring unique properties related to these magnetosomes' surface chemistry and surface area [4].

In alignment with the global demand for new approaches to treat antibiotic resistant infections, we have been exploring the potential of magnetosome based antimicrobial formulations. By pre-treating magnetosomes with the cationic polymer, poly-L-lysine, the β-lactam antibiotic, ampicillin, and the β-lactamase inhibitor, clavulanate were successfully bound to prismatic magnetosomes. For 100 µg of magnetosomes, mean capture capacities were 15,6 ± 3,37 µg and 21,2 ± 4,16 µg for ampicillin and clavulanate, respectively. In microdilution assays against a susceptible strain of *Staphylococcus aureus* the developed nanoformulation had a significantly higher effect on disrupting cell growth compared to the antibiotic alone in the same concentrations. In future research, the antimicrobial potential of the nanoformulation will be evaluated under the application of magnetic hyperthermia.

Even though magnetosomes' applications were explored in several areas, magnetic hyperthermia and drug delivery are the most studied topic, especially in cancer treatment, which covers 57.14% of publications. Thus, magnetosomes from strains AMB-1 and MSR-1 are the most used in these cases, which may be due to their well-established culture and optimised yield. Nevertheless, reports have also shown magnetosomes' potential in bioremediation. In this scenario, a wide variety of magnetosomes and their applications are still undiscovered, opening a great field of possibilities in Nanobiotechnology. Hopefully, the meta-analysis proposed here will indicate approaches in which magnetosomes could be efficiently applied.

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