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Green Synthesis of Magnetite (Fe_3O_4) nanoparticles from Cocos nucifera extract

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Abstract

The growing demand for sustainable solutions in recent years has driven the production of nanomaterials, such as magnetite (Fe_3O_4), widely used in various technological applications. However, its traditional synthesis involves toxic reagents and generates severe environmental impacts. In this context, green synthesis, using renewable natural extracts, emerges as a sustainable alternative to minimize these damages, integrating principles of Environmental Chemistry with waste management and treatment [1]. Based on this premise, this work proposed a methodology for the green synthesis of magnetite, using coconut fiber extract (Cocos nucifera) as a reducing and stabilizing agent, promoting a more eco-friendly production route. The process was divided into three main stages: biomass preparation, extract extraction, and nanoparticle synthesis. The nanoparticles were synthesized under different temperature conditions and extract concentrations and later characterized by X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and Mössbauer spectroscopy. XRD results confirmed the formation of the magnetite (Fe_3O_4) phase, with the extract significantly contributing to crystal growth, as it acts as a stabilizing agent, creating a protective layer around the nanoparticles. This coating prevents agglomeration while increasing stability in aqueous suspensions [2]. The results also indicated that using natural extract as a reducing agent simplifies the synthesis process by eliminating the need for additional chemical compounds and promoting the growth of nanoparticles with superior structural characteristics. It was observed that the samples synthesized in the presence of the extract had a larger average crystallite diameter compared to those obtained without the extract. The sample was synthesized without heating and with 5% extract (the best-performing sample in this regard, named MNT 01) and reached 11.4 nm. In the FTIR analysis, the presence of hydroxyl (O-H), carboxyl (C=O), and carbonyl (C-O) groups in the structure of the formed material were identified, indicating that these main groups incorporate Fen+ ions from the solution into the biomass, as is characteristic of the green synthesis process [3]. Mössbauer spectroscopy analysis revealed that the MNT 01 sample contained 33% Fe^{3+} and 67% Fe^{2+}, suggesting that it achieved the best approximation to the ideal stoichiometry of magnetite, reflected in its optimized magnetic and structural properties, while the other samples experienced partial oxidation and showed greater structural disorder [4]. Therefore, it can be concluded that the synthesis of magnetite nanoparticles with a larger crystallite diameter is an important factor, as it can improve not only their magnetic properties but also the material's structural stability, thus expanding its applications [5]. These results also highlight the potential of residual materials, such as coconut fiber, to replace conventional routes in nanoparticle synthesis, aligning with global guidelines for reducing the environmental impact caused by waste and promoting green technologies.
Key words: Magnetite; Coconut residue; Green synthesis; Nanoparticles

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